BC Environment

Organochlorine Contamination in Various Environmental Compartments Related to Chemical/Combustion Sources: Lower Mainland/Vancouver Island Skeena/Interior Regions

Prepared for:
B.C. Environment
Ministry of Environment, Lands and Parks
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ORGANOCHLORINE CONTAMINATION IN VARIOUS ENVIRONMENTAL COMPARTMENTS RELATED TO CHEMICAL/COMBUSTION SOURCES: LOWER MAINLAND/VANCOUVER ISLAND/ SKEENA/INTERIOR REGIONS

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EXECUTIVE SUMMARY

Hatfield Consultants Limited (HCL) was retained by the Ministry of Environment, Lands and Parks (MoELP) to perform a survey of dioxins and other chlorinated organic compounds in a variety of media collected from 23 different sites in the Lower Mainland, Vancouver Island, the Interior, and the Skeena regions. In total over 170 samples were analyzed for dioxins and furans, and a lesser number for organochlorine compounds and PCBs. In addition to replicate sample analyses, 52 blanks were also run for QA/QC (Quality Assurance/Quality Control) purposes. Sample sites were broadly divided into two main categories: sites potentially contaminated by chemical sources of dioxins and furans, and sites potentially contaminated by emissions from combustion sources (e.g., incinerators). The following media types were collected and analyzed: soils, sediments, foliage, shellfish and fish, sludge, ash, runoff and leachate. Each media type was categorized as being primary, secondary or background depending on its location relative to the source under study. The results of the dioxin/furan analyses determined in this survey were compared to levels found in other parts of the world (as determined by a literature review).

Levels of dioxins and furans in the media examined during this survey appear to fall within the same range of concentrations found in comparable sites in other parts of the world. Incinerator fly ash from combustion sources and soils/sediments from chemical sources were the most contaminated samples. However, the data does not conclusively demonstrate that either media is a significant source of public exposure. For example, high levels of dioxins and furans in fly ash may indicate that the precipitator is working well and there is little public exposure. High levels do, however, indicate the need for a more extensive site-specific evaluation (more samples collected, evaluations of emissions, etc.). A detailed inventory of contaminated sites, and more information of discharge rates from different sources, must be collected before a reasonable assessment of the potential for exposure to dioxins by the general public can be made.

Levels of selected organochlorine compounds also seem to fall within ranges found in other parts of the world. However, relatively few samples were analysed for organochlorine compounds, and it was not possible to make generalizations regarding levels of these compounds in the B.C. environment.

1.0 INTRODUCTION

Hatfield Consultants Limited (HCL) was initially contracted by the British Columbia Ministry of Environment, Lands and Parks (MoELP) to complete a survey of selected sites in B.C. in order to determine levels of dioxin/furan contamination in a variety of sample types. HCL was responsible for the collection, storage and shipping of samples to the analytical laboratory, tabulation and analysis of results, and meetings with Ministry staff to discuss the project. The scope of this program was later expanded to include other organochlorine compounds, namely PCB-congeners/coplanars and organochlorine compounds. Particle size and carbon (total, organic, and carbonate) were also performed on selected samples.

The primary purpose of this study is to ascertain levels of dioxins and furans near various possible sources and in the ambient British Columbia environment. These levels will be compared to levels found elsewhere in the world. MoELP selected sampling sites, which were broadly divided into two categories (combustion sources and chemical sources), and the laboratory which would perform the chemical analyses (Seakem Analytical Services Ltd. in Sidney B.C.).

Over one hundred and seventy samples from twenty-three sites were collected and analyzed. Pertinent data has been summarized and presented in both graphical and tabular formats in separate sections at the end of the report.

2.0 METHODS

The program involved the collection of eight sample types, or media, in three classifications: primary, secondary and background samples. The sample types were as follows:

- Soil - fine geomorphic surface material;
- Sediment - fine submerged silt/sand/clay;
- Ash - fine combustion product present at, or near, the source;
- Runoff - precipitation drainage;
- Leachate - liquid discharge attributable to the target source;
- Vegetation - leaf material; sometimes specifically pine needles;
- Sludge - process sediment deposit in containment facility; and
- Fish/Shellfish - usually designated as mussel (*Mytilus edulis*).

The three classifications (primary, secondary and background) were ascribed to samples on the basis of location of the collection site relative to location of the specified source. Facilities targeted for sampling were chosen by MoELP and at each facility, locations for sample collections were determined after discussions with MoELP and facility personnel.

Primary samples were taken at the source or as near the source as possible. Secondary samples were collected in the receiving environment where source material was expected to be transported by wind or water flow. Background samples were collected away from the source in areas not expected to receive contaminants from the primary source.

2.1 COLLECTION PROCEDURES

All procedures used to collect samples adhered to protocols specified for organochlorine sampling protocols developed by Environment Canada, Environmental Protection and B.C. Ministry of Environment, Lands and Parks, Waste Management.

Solid samples were collected using a stainless steel spoon and deposited into a stainless steel pan, both of which had been specially prepared to avoid contamination of the

sample. The sample was then thoroughly mixed, then transferred to the specially treated sample jar.

Submerged sediment samples were collected with an Ekman dredge in shallow water, and a Smith-McIntyre grab at deeper locations.

Liquid samples were taken by placing a Winchester bottle directly under the source or by first collecting the sample into a stainless steel pail, then transferring the sample to the bottle. In both situations the sampling followed protocol-specified procedure.

Vegetation was collected by hand from selected trees and shrubs in secondary and background locations. Latex gloves were worn to collect the largest leaves available. Shellfish samples of the largest size were collected by hand during low tides. Fish collection was facilitated using electroshocking equipment.

All samples were labelled according to specified protocols. All non-liquid samples were immediately frozen and liquid samples were kept cool and placed in cold storage.

3.0 BACKGROUND INFORMATION ON DIOXINS/FURANS

3.1 STRUCTURE

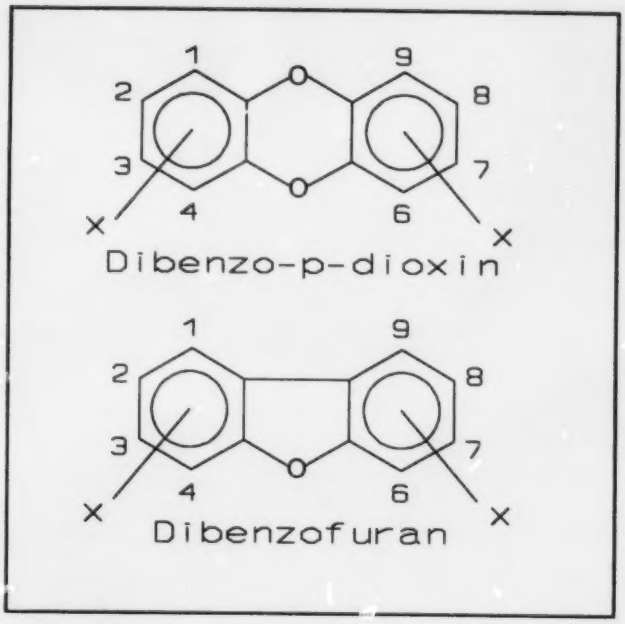

FIGURE 3-1

Polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF) consist of a series of almost planar tricyclic aromatic compounds that can be chlorinated in a variety of positions. The basic structural formulae are shown in Figure 3-1. Dioxins and furans can be substituted with between one to eight chlorine atoms attached at positions marked 1-4, 6-9. This gives rise to 75 different chlorinated dioxins and 135 different chlorinated furans. The toxicity of PCDD and PCDF is dependent on the degree of halogenation and on the location of the halogen atoms. The most toxic dioxin (the one commonly called "Dioxin" by the popular press) is substituted with four chlorine atoms attached at the 2,3,7,8 positions, and is therefore referred to as 2,3,7,8-tetrachlorodibenzodioxin or 2,3,7,8-TC_4DD (often it is abbreviated further to TCDD).

3.2 TOXICITY

Since the advent and widespread use of synthetic pesticides and other halogenated organic compounds, there has been an increasing global awareness of the harmful ecological effects that can arise from exposure to many of these compounds. The rise in public concern has largely paralleled improvements in analytical detection limits for many man-made contaminants.

One of the problems associated with developing regulations that would limit public exposure to dioxins is determining at what level of exposure there is a significant increase in health hazard. This problem is complicated due to the wide range in reported toxicities that different dioxin/furan congeners exhibit towards a single (animal) species. Research indicates that many congeners are more than 10,000 times less toxic than 2,3,7,8-TC_4DD, the most toxic dioxin/furan congener. There are also large differences in the susceptibility of different animal species to dioxins. For example, the guinea pig is approximately 1,000 times more susceptible to 2,3,7,8-TC_4DD than hamsters. Animal studies have also demonstrated that 2,3,7,8-TC_4DD can affect normal embryonic development in a range of animals including; rats, mice, rabbits and ferrets.

Data on the toxicity of dioxins and furans towards humans is far more limited. Most data has been obtained by observing populations that were inadvertently exposed to high concentrations of 2,3,7,8-TC_4DD as a result of industrial accidents. The events in Times Beach, Missouri, and Seveso, Italy where as many as 40,000 people were exposed, are probably the best known and most researched. Studies of these and other exposed populations seem to indicate that humans are not particulary sensitive to 2,3,7,8-TC_4DD. Initial high exposures resulted in the development of a specific type of acne called chloracne. Studies of workers who suffered from chronic exposure have *not yet* produced convincing evidence of elevated levels of cancer, heart disease or overall mortality (Harris 1990) among the exposed group compared to controls. A half-time of 4.95 years was reported for humans after the ingestion of a single dose of radiolabeled TC_4DD. Exposure of humans to dioxins is believed to increase the risk of soft tissue sarcoma (STS) (Eriksson et al. 1990), although much of the cancer epidemiology relating to TC_4DD and TC_4DF is inconclusive (Vainio et al. 1989; Skene et al. 1989). Despite the lack of direct evidence that the levels of dioxins and furans found in the environment pose a significant health threat to human populations, regulatory agencies agree that these compounds are undesirable environmental contaminants and that their unintentional production and release should be reduced as much as possible. In Canada, the Tolerable Daily Intake for dioxins and

furans is 10 pg 2,3,7,8-TCDD-TEQ[1] per kilogram body weight per day. This level of intake is believed to adequately protect human health (Birmingham et al. 1989b).

3.3 SOURCES

Three types of sources for dioxins and furans are: combustion, chemical and natural sources. The major contributors in the USA are listed in Table 3-1. The contributors on the list would likely be similar in Canada, although the order might be different (e.g., in B.C. the pulp and paper industry and forest fires would probably contribute more to the total).

TABLE 3-1

Estimated Dioxin Releases to the Environment (USA)-adapted from Stillman, 1990.

Source	Dioxin: TEQ kg/y
Municipal Waste Incinerators	21.1
Secondary Copper Smelters	4.4
Coal Combustion	4.0
Wood Combustion	1.9
Forest Fires	1.8
Magnesium Production	0.9
Municipal Waste Treatment Sludge	0.7
Bleached Pulp Manufacturing	0.55
Hospital Incinerator	0.5
Hazardous Waste Incineration	0.3
Municipal Sludge Incineration	0.2
Municipal Waste Treatment Effluent	0.1
Petroleum Refining	0.1
Other	0.2

a) Combustion Sources

In Canada, approximately 0.6 tonnes of garbage per person per year are incinerated. Fly ash precipitated from municipal incinerators has been found to contain dioxins. Dioxins have also been detected in the exhaust of automobiles which burn leaded gasolines. Various industrial processes such as smelters and refineries have been identified as dioxin and furan sources.

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1 An explanation of how TEQ values are calculated is provided in the Results Section (Section 4.0).

b) *Chemical Sources*

Dioxins are not deliberately synthesized, but are produced as contaminants in a variety of chemical processes. For chemicals manufacture, the following processes have been ranked in order of decreasing priority regarding levels of dioxins/furan contamination levels (NATO 1988a):

- Processes to manufacture chlorophenols and their derivatives;
- Processes to manufacture chlorobenzenes and substituted chlorobenzenes;
- Synthesis of aliphatic chlorine compounds;
- Methods involving chlorine-containing intermediates;
- Inorganic chlorochemical processes; and
- Processes applying chlorinated catalysts and solvents.

Industrial processes which can produce emissions containing dioxins include: the pulp and paper industry, municipal waste water treatment, pesticide production, metal production, the petroleum industry, etc.

c) *Natural Sources*

Pre-industrial age sediments (8,000 years old) have been found to contain detectable levels of dioxins and furans, suggesting that natural events (e.g., volcanoes or forest fires) are potential sources of dioxins/furans (Hashimoto 1990). Further research is required before an accurate assessment of the relative contribution that natural processes make to the global environmental dioxin levels can be made.

3.4 ENVIRONMENTAL LEVELS

TABLE 3-2

Typical Dioxin/Furan Levels in the Canadian Environment (Environment Canada, 1990)	
Medium	**Range in Concentration**
Ambient Air	0.4 to 36.7 pg total dioxins and furans per cubic metre
Ontario drinking water	Not detectable (ND) to 46 pg/L octachlorodibenzodioxin
Soil: Urban backyards, public areas and parkland	50 to 14,100 pg/g total dioxins and furans
Mammals	ND to 37 pg/kg 2,3,7,8-TC_4DD
Birds	ND to 1,996 pg/kg 2,3,7,8-TC_4DD
Reptiles	ND to 474 pg/kg 2,3,7,8-TC_4DD
Amphibians	ND to 35 pg/kg 2,3,7,8-TC_4DD
Crabs	ND to 662 pg/kg 2,3,7,8-TC_4DD
Shellfish	ND to 31 pg/kg 2,3,7,8-TC_4DD
Fish	ND to 137 pg/kg 2,3,7,8-$TC6_4DD$
Human fat tissues	3-10 pg/kg 2,3,7,8-TC_4DD/F

ND = not detected

Many chlorinated compounds are degraded only very slowly by natural processes and consequently, once they have been introduced into the environment, they tend to be persistent. Low levels of man-made chemicals can now be detected (due to advances in analytical chemistry) in areas that are far removed from centres of industrial activity. Data on the relative persistence of different dioxin congeners is not conclusive. Some reports claim that 2,3,7,8-TC_4DD has a degradation half-life of ten years or longer (in the absence of UV-light), while another report claims that only the most chlorinated dioxins (i.e., least toxic) are environmentally persistent (Eitzer and Hites 1989; Hites 1990) Dioxins and furans have been detected in many different media in Canada in samples collected from both rural and urban areas (Table 3-2).

4.0 RESULTS

- **Figures 1-4: Examples of dioxin/furan congener data presentation**
- **Figures 5-12: Total 2,3,7,8-TC_4DD TEQ values, Chemical Sources**
- **Figures 13-30: Total 2,3,7,8-TC_4DD TEQ values, Combustion Sources**

Since the toxic effects of most dioxins and furans are similar, but vary greatly in degree, an internationally accepted method for expressing the toxicity of different dioxins and furans on a common basis has been developed (NATO 1988a, 1988b). Toxic Equivalency Factors (TEF), determined through experimentation, have been assigned to individual dioxins and furans on the basis of how toxic they are in comparison with the toxicity of 2,3,7,8-TC_4DD, the most potent dioxin. 2,3,7,8-TC_4DD has been assigned a TEF value of 1. By comparison, research has determined that 1,2,3,7,8-Pentachlorodibenzodioxin is approximately half as toxic as 2,3,7,8-TC_4DD and consequently has a TEF of 0.5. In general, dioxins and furans that are substituted in the 2,3,7,8 positions are the most toxic and have 2,3,7,8-TCDD-TEQ values in the range of 0.001 to 0.5. Of the 210 possible dioxins and furans, the 17 listed in the Table 4-1 contribute most to the toxicity of a mixture of dioxins and furans.

All figures submitted in this report have dioxin and furan concentrations expressed as total 2,3,7,8-TC_4DD TEQ values. These values are calculated by multiplying each congener concentrations by its Toxicity Equivalency Factors (TEF) and summing the resulting products. These 2,3,7,8-TC_4DD-TEQ values are therefore representative of the overall dioxin/furan contamination levels in an individual sample.

Figures 1-4 are examples of dioxin/furan congener profiles plotted in three dimensions at two sites. The x-axis lists each of the samples collected from one site, the y-axis lists the congeners and the z-axis lists the concentration or TEQ value. These plots allow for the rapid assessment of the relative contributions that each congener/sample type make to the overall contamination of a site.

Figures 5-30 are standard two-dimensional plots of media type versus total TEQ values (i.e., the sum of the individual congener TEQ values) for each site. The plots summarize the relative contamination of each media type.

Dioxin/furan/organochlorine data from the current study have also been summarized in a series of tables; Tables 1 to 3 group samples into one of the following three groups: background, primary or secondary; Tables 4 to 9 group dioxin and furan by media type; Tables 10 to 13 list background levels of organochlorine compounds; Tables 14 to 18 list levels of organochlorine compounds in various media types; Tables 19 to 22 present National/International levels of dioxin and furans; and Tables 23 to 25 present National/International levels of the other organochlorine compounds.

TABLE 4-1

Toxicity Equivalency Factors (NATO, 1988a)	
Dioxin/Furan	Equivalency Factor
2,3,7,8-tetrachlorodibenzodioxin	1.0
1,2,3,7,8-pentachlorodibenzodioxin	0.5
1,2,3,4,7,8-hexachlorodibenzodioxin	0.1
1,2,3,7,8,9-hexachlorodibenzodioxin	0.1
1,2,3,6,7,8-hexachlorodibenzodioxin	0.1
1,2,3,4,6,7,8-heptachlorodibenzodioxin	0.01
octachlorodibenzodioxin	0.001
2,3,7,8-tetrachlorodibenzofuran	0.1
2,3,4,7,8-pentachlorodibenzofuran	0.5
1,2,3,7,8-pentachlorodibenzofuran	0.05
1,2,3,4,7,8-hexachlorodibenzofuran	0.1
1,2,3,7,8,9-hexachlorodibenzofuran	0.1
1,2,3,6,7,8-hexachlorodibenzofuran	0.1
2,3,4,6,7,8-hexachlorodibenzofuran	0.1
1,2,3,4,6,7,8-heptachlorodibenzofuran	0.01
1,2,3,4,7,8,9-heptachlorodibenzofuran	0.01
octachlorodibenzofuran	0.001

Background samples (Table 1) are defined as samples representative of ambient levels of dioxins and furans in the environment, without contribution from the source under investigation or any major (known) source of contamination. Background levels of 2,3,7,8-TC_4DD were below detection limit for all media types examined. This indicates that contamination by the most toxic dioxin congener is not widespread in the media surveyed in this study. However, 2,3,7,8-TC_4DF was detected in all background media types examined. The highest levels were detected in background soils and sediments, with average values of 5.9 pg/g

and 2.9 pg/g respectively. Soil and sediment samples also had the highest average total-TEQ values of all the media types sampled (11.1 and 10.8 pg/g respectively).

Primary samples (Table 2) are samples collected as close as reasonably possible to the source of the contamination and are representative of the levels of contaminants being generated by the source under study. Only three primary media types were collected: soils, ash and sludge. Ash is a part of the combustion process, whereas soil is not a part of the chemical or combustion process, and as expected primary ash samples had the highest average 2,3,7,8-TC_4DD/F concentrations (21.3 and 5,463 pg/g respectively). Primary ash samples were more contaminated, as measured by total-TEQ, than either primary soils or primary sludges.

Secondary samples (Table 3) are samples that were collected from areas directly impacted by the primary source and are an indication of the movement of the contaminants under study. Secondary soils collected in the vicinity of sites potentially contaminated by a chemical source were the most contaminated of all media examined in this category. Mean TCDD, TCDF and TEQ values were 59.8, 120 and 170 pg/g respectively. Secondary soils collected in the vicinity of sites potentially contaminated by combustion sources were significantly less contaminated. A similar trend was noted for secondary sediments, i.e. samples collected near chemical sources were more contaminated than those collected from near combustion sources. Secondary sediments (Table 3) collected from near chemical sites had the second highest total-TEQ value found (58.4 pg/g). 2,3,7,8-TC_4DD was not detected in any other secondary media type (foliage, shellfish, fish, runoff and leachate), except for low levels in some of the secondary runoff samples. Low levels of 2,3,7,8-TC_4DF were detected in all the media types examined, however the total-TEQ values were low compared to sediments and soils.

PCBs were widely used industrial chemicals and have become ubiquitous environmental contaminants. Its high stability contributed to both its commercial usefulness and its long-term deleterious environmental and health effects.

Our data indicates that PCBs are generally present in the highest concentration of the 23 organochlorine compounds analyzed. Concentrations were highest in primary soil samples (562.2 ng/g average), followed by secondary sediment (64.4 ng/g). Background samples (Tables 10-13) also contained delectable levels of PCBs (measured as Aroclor). pp'-DDT, pp'-DDE, cis-Monochlor, Dieldin, methoxychlor were also detected in moderately elevated concentrations (4-40 ng/g) in background soil samples collected. Biota were not contaminated with significant levels of organochlorine compounds with the exception of PCBs (as Aroclor) and o, p'-DDD. However, due to the small number of samples analyses, it was not possible to make generalizations regarding levels of organochlorine compounds in the B.C. environment.

5.0 CONCLUDING DISCUSSION

- **Figures 5-33**
- **Tables 1-25**

The following discussion is based largely on the total 2,3,7,8-TCDD-TEQ graphs presented in the Figures section of the report (Figures 5 to 33). The total 2,3,7,8-TCDD-TEQ value is the sum of the dioxin and furan congener 2,3,7,8-TCDD-TEQ values and is representative of the total contaminant loading of the sample. For this reason, it is probably the most comparable parameter between samples taken from different sites. To further facilitate direct comparisons, all total 2,3,7,8-TCDD-TEQ values from one site were plotted together (Figures 5 to 33), irrespective of concentration differences between the media types collected.

It must be emphasized that no attempt was made in this survey to assess environmental **loadings** from the various sources, all comparisons are based solely on **concentrations** of various contaminants. For example, even though a sample may be highly contaminated (as measured by total-TEQ) the overall environmental loading may be small if the volume released to the environment is small. Conversely, a sample with a very low overall contamination (as measured by total-TEQ), may be responsible for higher environmental loadings if the volume released to the environment is large.

Tables 19 through 25 provide a summary of dioxin/furan and organochlorine compound levels found in a number of different countries. Direct comparison of these levels with the data acquired during this survey was complicated in many cases due to differences in sampling methodologies, media types collected, congeners analyzed, etc. However, *in general*, the following points can be made:

A) ***Background Samples***

Soils

Background soil levels of dioxins and furans determined in this survey are comparable with levels found elsewhere in the world. For example, rural soils collected in Sweden had a total-TEQ range of 9-32 pg/g (Broman et al. 1990; Table 19), compared to a range of 2.3-37.8 pg/g for soils analyzed in this survey (Table 1).

Of the organochlorines measured during this survey, p,p'-DDT was determined to have the highest average concentration of organochlorine compound in the background soil samples collected (44.89 ng/g), followed by PCBs (13.1 ng/g). A primary metabolite of DDT (p,p'-DDE), cis-Nonachlor (3.85 ng/g), Dieldrin (3.99 ng/g) and Methoxychlor (3.84 ng/g) were also detected in moderately elevated concentrations.

Sediments

Background sediment levels of TCDD/F determined during this survey (ND for TCDD, ND-17.0 pg/g for TCDF; Table 1) are similar to those found in sediments from a Swedish river with no known dioxin inputs (ND for TCDD, 4.9-5.6 pg/g TCDF cited in Kjeller et al. 1990; Table 20). An oil refinery (Site A4ii) was anomalous in that background sediment exhibited the highest total 2,3,7,8-TCDD-TEQ value for any of the samples taken from that site. This result was not unreasonable given that the inlet from which the sediments were collected are the final sink for many contaminants, including dioxins, for a large number of industries on its shores. The high background sediment levels undoubtedly reflect historical inputs from a variety of industries. Sediments and soils were, in general, the most contaminated of all media examined in this survey. Leachate, mussels, fish and foliage generally exhibited low total 2,3,7,8-TCDD-TEQ values.

Other organochlorine compound levels in sediments were generally low or below detection limit. PCBs were present in the highest average concentration (17.82 ng/g), followed by p,p'-DDD (1.06 ng/g) (Table 11). All other organochlorine compounds were below 1.0 ng/g. Both DDE and PCB (as Aroclor) are ubiquitous environmental contaminants and have been detected in sediments collected from sites around the world (Table 23). Levels detected in samples collected during this survey fall within ranges found elsewhere in the world (Table 23).

Foliage

Background foliage levels determined during this survey were slightly lower than levels found in a comparable survey performed in the UK (Startin, Rose and Offen 1989). The UK study found concentrations of up to 9.7 ppt (parts per trillion; which is comparable to pg/g) 2,3,7,8-TCDD on background vegetation samples (Table 22). 2,3,7,8-TCDD was not detected in the current survey (Table 1). Foliage samples were not analyzed for organochlorine compounds during this survey.

Shellfish/Fish

Background levels of shellfish and fish have not been widely reported in the literature as most research has focused on collecting and analyzing biota from areas known to be polluted. However, research in Canada (Dwernychuk 1990 a,b,c,d,e,f,g) has shown that in areas removed from known sources of contamination, the levels of 2,3,7,8-TC_4DD and 2,3,7,8-TC_4DF are usually below detection limit. The low levels determined during this survey confirm this observation.

Levels of organochlorines detected in a background shellfish sample were generally low or below detection limit (Table 12). Only PCBs (as Aroclor, 20 ng/g) and o,p'-DDD (2.9 ng/g) were detected in concentrations above 1.0 ng/g. Similar results were noted for the levels detected a single fish sample (i.e PCBs [as Aroclor] were highest followed by o,p'-DDD; Table 13). However, based on a single sample it is not possible to make generalizations regarding

levels of organochlorine compounds in background shellfish or fish in BC. Table 25 lists organochlorine compound levels found in biota from different regions of the world and confirms our data which suggests that PCB are an ubiquitous contaminant in biota.

B) Primary and Secondary Soils

Literature ranges for primary and secondary soils were highly variable (Table 19). Samples from contaminated sites had values in the high ppb (parts per billion) range (Umbriet 1986, Sievers and Friesel 1989). These values indicate a far higher degree of contamination than found in any of the samples collected during this survey. An Environment Canada report (Environment Canada 1990) lists a range of between 50 and 14,100 pg/g for total dioxins and furans in soils collected in Canada. In general, soils collected from a variety of sites in B.C. (Table 4) do not appear to be excessively contaminated with dioxins and furans compared to similar sites in other parts of the world (Table 19).

Individual soil samples collected during this survey had elevated concentrations of dioxins and furans. Specifically, primary soils for B3a and B3b, and secondary soils from A3a, A5bi, B3a, B3b, B4i, B12, B14 and B18b had elevated 2,3,7,8-TCDD TEQ values. Figure 32 illustrates that secondary soils collected during this survey had an average total 2,3,7,8-TC_4DD TEQ of over 100 pg/g, the highest of any of the secondary media collected. It should be noted that primary soils often have lower total-TEQ values than secondary soils. This could be a result of random distribution caused by small sample size and/or the fact that heavily contaminated sites are frequently excavated and filled with clean soil.

Organochlorine compound levels in a single primary soil sample analyzed are presented in Table 14. PCBs (as Aroclor, 562.5 ng/g) was detected in the highest concentration. o,p'-DDD and p,p'-DDT were detected in lower concentrations (4.04 ng/g and 2.25 ng/g) respectively. Secondary soils were contaminated with a wide range of organochlorine compounds including (Table 15): PCBs (as Aroclor 39.17 ng/g), p,p'-DDT (16.9 ng/g), p,p'-DDE (8.82 ng/g),

Heptachlor epoxide (5.72 ng/g), p,p'-DDD (4.18 ng/g), cis-Nonachlor (1.42 ng/g) and o,p'-DDD (1.17 ng/g). All other organochlorine compounds concentrations were below 1.0 ng/g.

C) Secondary Sediments

Sediment samples analyzed for dioxins and furans from this survey (Table 5) appeared to be less contaminated than sediments collected elsewhere in Canada or the world (Table 20). However, only a limited number of sediments were collected during this survey, and the values listed in Table 5 may not be representative of levels in sediment, collected from impacted areas within BC.

Sediments were contaminated with a range of organochlorines, most notably PCBs (64.4 ng/g), p,p'-DDE (10.13 ng/g) and o,p'-DDD (1.75 ng/g). Levels of other organochlorine compounds were below 1.0 ng/g. Levels of selected organochlorine compounds found in sediments collected from other parts of the world are presented in Table 23 and suggest that levels detected in BC are comparable to levels found elsewhere.

D) Secondary Foliage

Levels of dioxins and furans found in secondary foliage during this survey (Table 6), are similar to those reported for vegetation collected in the vicinity of an American power plant (Reed et al. 1990; Table 22). Data suggest that accumulation of dioxins and furans in above ground plants mainly results from atmospheric deposition of gaseous and particulate phase TCDD/F (Reischl et al. 1989). Foliage samples were not analyzed for organochlorine compounds.

E) Shellfish and Fish

Levels of TCDD/F detected during this survey (Table 7) were close to or below detection limit for all samples. These levels are lower than might be expected for biota caught

in the proximity of an emission source. The low values may be a reflection of low release to the environment, or the limited sample size. Previous studies (Dwernychuk 1990 a,b,c,d,e,f,g) have indicated that dioxins and furans tend to accumulate in specific organs, e.g., fish liver or crab hepatopancreas. Whole body concentrations of TCDD/F may therefore be below detection, even if significant accumulations are occurring in specific organs.

PCBs were the only organochlorines detected in secondary shellfish in concentrations above 1.0 ng/g (Table 17). However, of the 22 organochlorines analyzed for, only 5 were below detection limit, demonstrating that the shellfish was being exposed to a wide range of chlorinated organics. A similar pattern was observed for the organochlorine compound profile in secondary fish, with a wide range of organochlorine compounds being detected in the two analyzed samples. PCBs and p,p'-DDE were detected in the highest average concentrations (8.3 ng/g and 3.45 ng/g respectively). Levels of organochlorines in fish and shellfish collected from a number of countries reveal that PCB (as Aroclor) concentrations tend to be the highest on average (Table 25). Lower concentrations of DDE and HCB were also detected in a number of samples. The small sample size make it difficult to make generalizations regarding organochlorine compound concentrations in biota. Levels detected fall within the ranges found in Canada and other parts of the world (Table 25).

F) Sludge and Ash Samples

Ash samples represent some of the most contaminated samples collected during the present survey (Table 8). TCDD concentrations (not cited in Table 8) ranged between ND and 370 pg/g, which is a far greater range than reported in an earlier study of municipal waste incinerator fly ash in Japan, Canada and the Netherlands (Finkel et al. 1990; Table 21). Municipal incinerators in Italy (Bagnati et al. 1990) reported a total TCDD range of between ND and 2.86 ng/g. A greater range and similar to that seen in this study for TCDD was reported by Brown et al. (1990) for fly ash collected from Municipal, Clinical and Chemical Incinerators in the U.K. (12-360 ng/g; Table 21).

5.1 SUMMARY

Ash samples not surprisingly had the highest level of contamination. Primary fly ash from a Hospital incinerator (B4ii) and a smelter (B17) exhibited extremely high total 2,3,7,8-TCDD-TEQ values (Figures 18 and 28), in excess of 20,000 and 50,000 pg/g, respectively. These two samples represented the most contaminated samples collected during the entire study. The low level contamination in other media samples collected at site B17 and B4ii indicates that the fly ash being generated may be effectively contained and is probably not escaping into the environment. However, the high levels of dioxins and furans detected in the above samples warrant a more detailed evaluation of these sites.

In summary, concentrations of dioxins and furans found in various media types collected in B.C. appear to fall within the same range as those found in similar locations in other parts of the world. A more extensive data set on background levels in BC will be acquired over the next year. Only a few grab samples were collected from each site, and consequently it is very difficult to assess the relative contribution each site makes to overall environmental contamination. Sites with high levels of contamination probably warrant a more intensive evaluation of the site. This monitoring will be undertaken by the Ministry or the site owner. More information on discharge rates from different sources is required before an assessment of relative contributions of different dioxin/furan inputs into the environment from different sources can be made. This information will be considered before further monitoring is undertaken at various sites.

Organochlorines contamination tended to be highly site-specific, with PCBs generally being present in the highest concentration. PCB-congener and coplanar contamination also tended to be highly site-specific and no obvious correlations between sample type and contaminant levels could be deduced from the limited data set. Levels of selected organochlorine compounds seem to fall within ranges found in other parts of the world. However, only a limited number of samples were analyzed for organochlorines, making it difficult to generalize about

environmental levels in B.C. Biota apparently accumulate a range of organochlorines and a more extensive survey of potentially affected areas would be useful.

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TABLE 1: BACKGROUND[1] LEVELS OF DIOXINS/FURANS (CHEMICAL/COMBUSTION SOURCES) IN THE B.C. ENVIRONMENT (1990-91)

SAMPLE CATEGORY	Dioxin and Furan Concentrations (pg/g)[2]		Total 2,3,7,8 TC_4DD-TEQ values(pg/g)[2,3]	
	Range	Mean[4]	Range	Mean[4]
Background Soils · 2,3,7,8-TC_4DD[5] · 2,3,7,8-TC_4DF[6]	 ND ND-22.0	 ND (11) 5.9 (11)	2.3 - 37.8	11.1 (14)
Background Sediments · 2,3,7,8-TC_4DD · 2,3,7,8-TC_4DF	 ND ND-17.0	 ND (7) 2.4 (7)	2.2 - 33.0	10.8 (7)
Background Foliage · 2,3,7,8-TC_4DD · 2,3,7,8-TC_4DF	 ND ND-2.3	 ND (6) 0.4 (6)	2.1-4.9	2.9 (7)
Background Shellfish · 2,3,7,8-TC_4DD · 2,3,7,8-TC_4DF	 - -	 ND (1) 4.2 (1)	 - -	3.7 (1)
Background Fish · 2,3,7,8-TC_4DD · 2,3,7,8-TC_4DF	 - -	 ND (1) 1.2 (1)	 - -	1.8 (1)
Background Surface Runoff · 2,3,7,8-TC_4DD · 2,3,7,8-TC_4DF	 - -	 ND (1) ND (1)	-	0.009 pg/mL (1)

1 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

2 All concentrations in pg/g except where noted. Soils and sediments are dry weight; tissue and foliage are wet weight. Liquid samples have been expressed as pg/mL to allow a more direct comparison with other media types which are expressed as pg/g.

3 Total-TEQ values refer to the sum of the TEQ values, calculated according to the MOE guidelines, for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

4 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

5 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

6 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 2: PRIMARY[1] LEVELS OF DIOXINS/FURANS (CHEMICAL/COMBUSTION SOURCES) IN THE B.C. ENVIRONMENT (1990-1991)

SAMPLE CATEGORY	Dioxin and Furan Concentrations (pg/g)[2]		Total 2,3,7,8-TC_4DD-TEQ values[3] (pg/g)[2]	
	Range	Mean[4]	Range	Mean[4]
Primary Soils				
· 2,3,7,8-TC_4DD[7]	ND-3.5 pg/g	0.4 (18)	2.1-65.2	13.1 (18)
· 2,3,7,8-TC_4DF[8]	ND-76.0 pg/g	14.1 (18)		
Primary Ash Samples[5]				
· 2,3,7,8-TC_4DD	ND-410.0	21.3 (22)	3.3-53,905.0	4,044.3 (22)
· 2,3,7,8-TC_4DF	ND-86,000.0	5,463.2 (22)		
Primary Sludge[6]				
· 2,3,7,8-TC_4DD	ND-0.03 ND-	0.01 (4)	1.1-15.4	8.4 (4)
· 2,3,7,8-TC_4DF	0.5	14.1 (4)		

1 Primary samples are samples collected as close as reasonably possible to the source of the contaminants and is representative of the levels of contaminants being generated.

2 All concentrations in pg/g except where noted. Soils and sludge are expressed as dry weight, tissue and foliage as wet weight. Liquid samples have been expressed as pg/mL to allow a more direct comparison with with other media types which are expressed as pg/g.

3 Total-TEQ values refer to the sum of the TEQ values, calculated according to MOE guidelines, for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

4 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

5 Three sites, B4ii, B8 and B17 were extremely contaminated (22,000, 10,500 and 54,000 pg/g total 2,3,7,8-TC_4DD-TEQs, respectively). The next highest total-TEQ value was 890. Consequently, mean values were strongly biased upwards. If the above three sites are omitted, mean values were:

- 2,3,7,8-TC_4DD = 3.1 pg/g
- 2,3,7,8-TC_4DF = 157.4 pg/g
- Total 2,3,7,8-TC_4DD-TEQ = 85.5 pg/g

6 The sludge sample from A5a was analyzed as an effluent and the concentration expressed as pg/L. These values were converted to pg/mL (roughly equivalent to pg/g) for comparison and averaging in the above table with the other samples (A5bii and B16).

7 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

8 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 3: SECONDARY[1] LEVELS OF DIOXINS/FURANS (CHEMICAL/COMBUSTION SOURCES) IN THE B.C. ENVIRONMENT - 1990/91

SAMPLE CATEGORY	Dioxin and Furan Concentrations (pg/g)[2]		Total 2,3,7,8-TC_4DD-TEQ[3] values (pg/g)[2]	
	Range	Mean[4]	Range	Mean[4]
Secondary Soils: Chemical Sources[5]				
· 2,3,7,8-TC_4DD[6]	ND-550.0	59.8 (10)	2.6-893.0	170.0 (10)
· 2,3,7,8-TC_4DF[6]	ND-550.0	120.0 (10)		
Secondary Soils: Combustion Sources[5]				
· 2,3,7,8-TC_4DD	ND-5.6	0.2 (42)	2.1-475.0	37.1 (42)
· 2,3,7,8-TC_4DF	ND-180.0	9.9 (42)		
Secondary Sediments: Chemical[6]				
· 2,3,7,8-TC_4DD	ND-2.7	0.5 (7)	4.2-193.6	58.4 (7)
· 2,3,7,8-TC_4DF	ND-33.0	7.6 (7)		
Secondary Sediments: Combustion[5]				
· 2,3,7,8-TC_4DD	ND-1.1	0.2 (5)	2.5-63.6	22.9 (5)
· 2,3,7,8-TC_4DF	ND-12.0	4.2 pg/g (5)		
Secondary Foliage				
· 2,3,7,8-TC_4DD	ND	ND (13)	1.4-3.3	2.4 (13)
· 2,3,7,8-TC_4DF	ND-8.5	1.6 (13)		
Secondary Shellfish				
· 2,3,7,8-TC_4DD	ND	ND (7)	2.0-3.4	2.6 (7)
· 2,3,7,8-TC_4DF	ND-17.0	5.1 (7)		
Secondary Fish				
· 2,3,7,8-TC_4DD	ND	ND (2)	1.4-2.6	2.1 (2)
· 2,3,7,8-TC_4DF	ND-2.0	1.0 (2)		
Secondary Runoff[6]				
· 2,3,7,8-TC_4DD	ND-.07pg/mL	.09 pg/mL (8)	0.002-10.5 pg/mL	1.3 pg/mL (8)
· 2,3,7,8-TC_4DF	ND-1.7pg/mL	218.0 pg/mL (8)		
Secondary Leachate[7]				
· 2,3,7,8-TC_4DD	ND	ND (5)	0.01-29.0 pg/mL	6.0 pg/mL (5)
· 2,3,7,8-TC_4DF	ND-2.1 pg/mL	0.6 (5)		

1 Secondary samples were collected from areas directly impacted by the primary source and are an indication of the movement of the contaminants under study.

2 All concentrations in pg/g except where noted. Soils and sediments are dry weight; tissues and foliage are wet weight. Liquid samples have been expressed as pg/mL to allow a more direct comparison with other media types which are expressed as pg/g.

3 Total-TEQ values refer to the sum of the TEQ values, calculated according to MOE guidelines, for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

4 Numbers in parentheses refer to the number of samples (*N*) used to calculate the mean.

5 Results from the soil and sediment analyses were divided into chemical and combustion sources due to the large number of samples. Results for all other sample categories represent the means and ranges covering <u>both</u> chemical and combustion sources.

6 Site B13 was highly contaminated (10,484.3 or 10.5 pg/mL total-TEQ). The next highest total-TEQ value is 0.1 pg/mL. Consequently, mean values were strongly biased upwards. If B13 is omitted from the calculations, mean values are:

- 2,3,7,8-TC_4DD = 0.001 pg/mL
- 2,3,7,8-TC_4DF = 0.006 pg/mL
- Total 2,3,7,8-TC_4DD-TEQ = 0.033 pg/mL

7 Site B8 was highly contaminated (29.0 pg/mL total-TEQ). The next highest total-TEQ value is 0.9 pg/mL. Consequently, mean values were strongly biased upwards. If Site B8 is omitted from the calculations, mean values are:

- 2,3,7,8-TC_4DD = ND
- 2,3,7,8-TC_4DF = 0.279 pg/mL
- Total 2,3,7,8-TC_4DD-TEQ = 0.225 pg/mL

8 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

9 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 4: DIOXIN/FURAN LEVELS IN THE B.C. ENVIRONMENT (1990-91)[1] : SOILS

SAMPLE CATEGORY[2]	Dioxin and Furan Concentrations (pg/g)[3]		Total 2,3,7,8-TC_4DD-TEQ values (pg/g)[3,4]	
	Range	Mean[5]	Range	Mean[5]
Background Soils				
· 2,3,7,8-TC_4DD[6]	ND	ND (11)	2.3-25.3	11.1
· 2,3,7,8-TC_4DF[7]	ND-22.0	5.9 (11)		
Primary Soils				
· 2,3,7,8-TC_4DD	ND-2.1	0.8 (5)	4.1-40.8	20.0
· 2,3,7,8-TC_4DF	ND-69.0	24.3 (5)		
Secondary Soils (Chemical Sources)				
· 2,3,7,8-TC_4DD	ND-292.0	49.8 (6)	2.6-617.5	180.0 (6)
· 2,3,7,8-TC_4DF	ND-500.0	100.0 (6)		
Secondary Soils (Combustion Sources)				
· 2,3,7,8-TC_4DD	ND-1.9	0.1 (14)	3.2-301.7	45.3 (14)
· 2,3,7,8-TC_4DF	ND-61.4	9.3 (14)		

1 Sampling sites were divided into two broad categories, those impacted by Chemical sources and those impacted by Combustion sources. The values listed in the table represent ranges and averages for <u>all</u> samples (chemical and combustion) for a given media type. If however, a sufficently large number of samples were collected from both chemical and combustion sources, then the Sample Category column was sub-divided and means and ranges were provided for each source type.

2 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

Primary samples refer to samples collected as close as reasonably possible to the source and representative of the level of contaminants being generated.

Secondary samples refer to samples directly impacted by the primary source and indicate movement of the contaminants under study.

3 All concentrations in pg/g (dry weight).

4 Total-TEQ values refer to the sum of the TEQ values, calculated according to the MOE guideline for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

5 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

6 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

7 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 5: DIOXIN/FURAN LEVELS IN THE B.C. ENVIRONMENT (1990-91)[1] : SEDIMENTS

SAMPLE CATEGORY[2]	Dioxin and Furan Concentrations (pg/g)[3]		Total 2,3,7,8-TC_4DD-TEQ values (pg/g)[3,4]	
	Range	Mean[5]	Range	Mean[5]
Background Sediment				
· 2,3,7,8-TC_4DD[6]	ND	ND (7)	1.7-33.0	10.8 (7)
· 2,3,7,8-TC_4DF[7]	ND-17.0	2.4 (7)		
Secondary Sediment (Chemical Sources)				
· 2,3,7,8-TC_4DD	ND-2.7	0.5 (6)	4.2-193.6	63.7 (6)
· 2,3,7,8-TC_4DF	ND-33.0	7.4 (6)		
Secondary Sediment (Combustion Sources)				
· 2,3,7,8-TC_4DD	ND-0.6	0.1 (4)	2.5-47.4	16.8 (14)
· 2,3,7,8-TC_4DF	ND-12.0	4.1 (4)		

1 Sampling sites were divided into two broad categories, those impacted by Chemical sources and those impacted by Combustion sources. The values listed in the table represent ranges and averages for <u>all</u> samples (chemical and combustion) for a given media type. If however, a sufficently large number of samples were collected from both chemical and combustion sources, then the Sample Category column was sub-divided and means and ranges were provided for each source type.

2 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

Secondary samples refer to samples directly impacted by the primary source and indicate movement of the contaminants under study.

3 All concentrations in pg/g (dry weight).

4 Total-TEQ values refer to the sum of the TEQ values, calculated according to the MOE guideline for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

5 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

6 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

7 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 6: DIOXIN/FURAN LEVELS IN THE B.C. ENVIRONMENT (1990-91)[1] : FOLIAGE

SAMPLE CATEGORY[2]	Dioxin and Furan Concentrations (pg/g)[3]		Total 2,3,7,8-TC_4DD-TEQ values (pg/g)[3,4]	
	Range	Mean[5]	Range	Mean[5]
Background Foliage				
· 2,3,7,8-TC_4DD[6]	ND	ND (6)	2.1-4.9	2.9 (6)
· 2,3,7,8-TC_4DF[7]	ND-2.3	0.4 (6)		
Secondary Foliage				
· 2,3,7,8-TC_4DD	ND	ND (12)	1.4-3.8	2.5 (12)
· 2,3,7,8-TC_4DF	ND-8.5	1.8 (12)		

1 Sampling sites were divided into two broad categories, those impacted by Chemical sources and those impacted by Combustion sources. The values listed in the table represent ranges and averages for all samples (chemical and combustion) for a given media type. If however, a sufficently large number of samples were collected from both chemical and combustion sources, then the Sample Category column was sub-divided and means and ranges were provided for each source type.

2 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

Secondary samples refer to samples directly impacted by the primary source and indicate movement of the contaminants under study.

3 All concentrations in pg/g (wet weight).

4 Total-TEQ values refer to the sum of the TEQ values, calculated according to the MOE guideline for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

5 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

6 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

7 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 7: DIOXIN/FURAN LEVELS IN THE B.C. ENVIRONMENT (1990-91)[1] : SHELLFISH AND FISH SAMPLES

SAMPLE CATEGORY[2]	Dioxin and Furan Concentrations (pg/g)[3]		Total 2,3,7,8-TC_4DD-TEQ values (pg/g)[3,4]	
	Range	Mean[5]	Range	Mean[5]
Background Shellfish				
· 2,3,7,8-TC_4DD[6]	-	ND (1)	-	3.7 (1)
· 2,3,7,8-TC_4DF[7]	-	4.2 (1)		
Secondary Shellfish				
· 2,3,7,8-TC_4DD	ND	ND (5)	2.0-3.4	2.6 (5)
· 2,3,7,8-TC_4DF	ND-17	6.1 (5)		
Background Fish				
· 2,3,7,8-TC_4DD	-	ND (1)	-	1.8 (1)
· 2,3,7,8-TC_4DF	-	1.2 (1)		
Secondary Fish				
· 2,3,7,8-TC_4DD	ND	ND (2)	1.4 - 2.7	
· 2,3,7,8-TC_4DF	ND (2.0)	1.0 (2)		2.1 (2)

1 Sampling sites were divided into two broad categories, those impacted by Chemical sources and those impacted by Combustion sources. The values listed in the table represent ranges and averages for all samples (chemical and combustion) for a given media type. If however, a sufficently large number of samples were collected from both chemical and combustion sources, then the Sample Category column was sub-divided and means and ranges were provided for each source type.

2 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

Secondary fish or shellfish refer to samples directly impacted by the primary source and indicate movement of the contaminants under study.

3 All concentrations in pg/g (wet weight).

4 Total-TEQ values refer to the sum of the TEQ values, calculated according to the MOE guideline for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

5 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

6 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

7 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 8: DIOXIN/FURAN LEVELS IN THE B.C. ENVIRONMENT (1990-91)[1] : SLUDGE AND ASH SAMPLES

SAMPLE CATEGORY[2]	Dioxin and Furan Concentrations (pg/g)[3]		Total 2,3,7,8-TC_4DD-TEQ values (pg/g)[3,4]	
	Range	Mean[5]	Range	Mean[5]
Primary Sludge				
· 2,3,7,8-TC_4DD[7]	ND	0.01 (3)	1.1-13.1	6.9 (3)
· 2,3,7,8-TC_4DF[8]	ND-28.0	9.5 (3)		
Primary Ash[6]				
· 2,3,7,8-TC_4DD	ND-410	30.7 (14)	3.7-53,905.6	5,930.4 (14)
· 2,3,7,8-TC_4DF	ND-86,000	8,228.9 (14)		

1 Sampling sites were divided into two broad categories, those impacted by Chemical sources and those impacted by Combustion sources. The values listed in the table represent ranges and averages for all samples (chemical and combustion) for a given media type. If however, a sufficently large number of samples were collected from both chemical and combustion sources, then the Sample Category column was sub-divided and means and ranges were provided for each source type.

2 Primary samples refer to samples collected as close as reasonably possible to the source and representative of the level of contaminants being generated.

3 All concentrations in pg/g (dry weight).

4 Total-TEQ values refer to the sum of the TEQ values, calculated according to the MOE guideline for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

5 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

6 Three sites (B4ii, B8 and B17) were extremely contaminated (22,847, 5,301, and 53,905 pg/g Total 2,3,7,8-TC_4DD-TEQs respectively). Consequently, mean values were strongly biased upwards. If the above three sites are omitted mean values are:

2,3,7,8-TC_4DD	-	1.8 pg/g
2,3,7,8-TC_4CF	-	145.8 pg/g
total 2,3,7,8-TC_4DD-TEQ	-	88.4 pg/g

7 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

8 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 9: DIOXIN/FURAN LEVELS IN THE B.C. ENVIRONMENT (1990-91)[1] : RUNOFF AND LEACHATE SAMPLES

SAMPLE CATEGORY[2]	Dioxin and Furan Concentrations (pg/L)[3]		Total 2,3,7,8-TC_4DD-TEQ values (pg/L)[3,4]	
	Range	Mean[5]	Range	Mean[5]
Background Runoff				
· 2,3,7,8-TC_4DD[8]	-	ND (1)	-	0.9 (1)
· 2,3,7,8-TC_4DF[9]	-	ND (1)		
Secondary Runoff[6]				
· 2,3,7,8-TC_4DD	ND-70	9.395 (8)	2.27-10,484.3	1,339.42 (8)
· 2,3,7,8-TC_4DF	ND-1700	217.89 (8)		
Secondary Leachate[7]				
· 2,3,7,8-TC_4DD	ND	ND (5)	9.8-29,039.0	5,987.5 (5)
· 2,3,7,8-TC_4DF	ND-21,000	4,423.1 (5)		

1 Sampling sites were divided into two broad categories, those impacted by Chemical sources and those impacted by Combustion sources. The values listed in the table represent ranges and averages for all samples (chemical and combustion) for a given media type. If however, a sufficently large number of samples were collected from both chemical and combustion sources, then the Sample Category column was sub-divided and means and ranges were provided for each source type.

2 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

Secondary samples refer to samples directly impacted by the primary source and indicate movement of the contaminants under study.

3 All concentrations in pg/L, which correspond to ppq (parts per quadrillion). In order to compare with other media, it is necessary to divide values by 1,000 to obtain pg/ml, which is comparable to pg/g. This calculation has been done on all other tables and figures.

4 Total-TEQ values refer to the sum of the TEQ values, calculated according to the MOE guideline for all measured congeners. MOE calculations use NATO (NATO 1988a) toxic equivalency factors and assume that the concentration of below detection limit congeners is equal to half the detection limit.

5 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

6 Site B13 was extremely contaminated (10,484.3 Total-TEQ) the next highest value was 135. Consequently, mean values were strongly biased upwards. If B13 is omitted from the calculations, mean values are:

2,3,7,8-TC_2DD	-	0.7 pg/L
2,3,7,8-TC_4DF	-	6.2 pg/L
Total 2,3,7,8-TC_4DD-TEQ	-	33.0 pg/L

7 Site B8 was extremely contaminated (29,039 pg/L Total-TEQ). The next highest TEQ value was 867.1. Consequently, mean values were strongly biased upwards. If B8 is omitted from the calculations, mean values were:

2,3,7,8-TC_4DD	-	ND pg/L
2,3,7,8-TC_4DF	-	278.9 pg/L
Total 2,3,7,8-TC_4DD-TEQ	-	224.6 pg/L

8 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

9 2,3,7,8-Tetrachlorodibenzofuran.

TABLE 10: BACKGROUND[1] LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): SOILS

Compound[3]	Concentration (ng/g)	
	Range	Mean[2]
HCB	ND-0.20	0.05 (10)
Heptachlor	ND	ND
Aldrin	ND	ND
o,p'-DDE	ND-2.5	0.30 (10)
trans-Nonachlor	ND-1.21	0.15 (10)
p,p'-DDE	ND-44.5	5.85 (10)
Mirex	ND	ND
alpha-BHC	ND-0.35	0.11 (10)
beta-BHC	ND	ND
gamma-BHC	ND-0.26	0.04 (10)
Oxychlordane	ND-0.20	0.02 (10)
trans-Chlordane	ND-1.91	0.30 (10)
cis-Chlordane	ND-1.51	0.23 (10)
o,p'-DDD	ND-6.45	1.20 (10)
p,p'-DDD	ND-25.1	4.0 (10)
cis-Nonachlor	ND-37.5	3.85 (10)
p,p'-DDT	ND-385	44.89 (9)
Heptachlor epoxide	ND-6.2	1.18 (10)
alpha-Endosulphan	ND-8.61	1.03 (10)
Dieldrin	ND-37.5	3.99 (10)
Endrin	ND-1.8	0.18 (10)
Methoxychlor	ND-34	3.84 (10)
PCBs (as Aroclor 1254/1260)	ND-72	13.1

1 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 11: BACKGROUND[1] LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): SEDIMENTS

Compound[3]	Concentration (ng/g)	
	Range	Mean[2]
HCB	ND-0.34	0.11 (5)
Heptachlor	ND	ND
Aldrin	ND	ND
o,p'-DDE	ND	ND
trans-Nonachlor	ND	ND
p,p'-DDE	ND	ND
Mirex	ND	ND
alpha-BHC	ND-0.52	0.14 (5)
beta-BHC	ND	ND
gamma-BHC	ND	ND
Oxychlordane	ND	ND
trans-Chlordane	ND-0.22	0.04 (5)
cis-Chlordane	ND-0.22	0.08 (5)
o,p'-DDD	ND-0.90	0.18 (5)
p,p'-DDD	ND-3.4	1.06 (5)
cis-Nonachlor	ND	ND
p,p'-DDT	ND-1.8	0.40 (5)
Heptachlor epoxide	ND-0.14	0.03 (5)
alpha-Endosulphan	ND-1.9	0.38 (5)
Dieldrin	ND	ND
Endrin	ND	ND
Methoxychlor	ND	ND
PCBs (as Aroclor 1254/1260)	ND-50	17.82 (5)

1 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane, PCBs - Polychlorinated Biphenyls.

TABLE 12: BACKGROUND[1] LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): SHELLFISH

Compound[4]	Concentration (ng/g)	
	Range	Mean[2]
HCB	-	0.05 (1)
Heptachlor	-	ND
Aldrin	-	N/A[3]
o,p'-DDE	-	ND
trans-Nonachlor	-	0.1 (1)
p,p'-DDE	-	0.48 (1)
Mirex	-	ND
alpha-BHC	-	0.09 (1)
beta-BHC	-	0.04 (1)
gamma-BHC	-	0.02 (1)
Oxychlordane	-	ND
trans-Chlordane	-	0.07 (1)
cis-Chlordane	-	0.12 (1)
o,p'-DDD	-	2.9 (1)
p,p'-DDD	-	0.22 (1)
cis-Nonachlor	-	0.09 (1)
p,p'-DDT	-	0.56 (1)
Heptachlor epoxide	-	ND
alpha-Endosulphan	-	ND
Dieldrin	-	ND
Endrin	-	ND
Methoxychlor	-	ND
PCBs (as Aroclor 1254/1260)	-	20 (1)

1 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 This sample was not analyzed.

4 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 13: BACKGROUND[1] LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): FISH

Compound[4]	Concentration (ng/g)	
	Range	Mean[2]
HCB	-	0.16 (1)
Heptachlor	-	ND
Aldrin	-	N/A[3]
o,p'-DDE	-	ND
trans-Nonachlor	-	0.14 (1)
p,p'-DDE	-	0.62 (1)
Mirex	-	0.18 (1)
alpha-BHC	-	ND
beta-BHC	-	ND
gamma-BHC	-	ND
Oxychlordane	-	ND
trans-Chlordane	-	ND
cis-Chlordane	-	0.08 (1)
o,p'-DDD	-	1.3 (1)
p,p'-DDD	-	ND
cis-Nonachlor	-	ND
p,p'-DDT	-	ND
Heptachlor epoxide	-	ND
alpha-Endosulphan	-	ND
Dieldrin	-	ND
Endrin	-	ND
Methoxychlor	-	ND
PCBs (as Aroclor 1254/1260)	-	38 (1)

1 Background samples are defined as samples indicative of ambient levels of compounds under scrutiny in the environment without contribution from the source under investigation or any other major source of contamination.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 This sample was not analyzed.

4 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 14: LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): PRIMARY[1] SOIL

Compound[3]	Concentration (ng/g)	
	Range	Mean[2]
HCB	-	0.016 (1)
Heptachlor	-	ND
Aldrin	-	ND
o,p'-DDE	-	ND
trans-Nonachlor	-	ND
p,p'-DDE	-	ND
Mirex	-	ND
alpha-BHC	-	0.01 (1)
beta-BHC	-	ND
gamma-BHC	-	ND
Oxychlordane	-	ND
trans-Chlordane	-	0.50 (1)
cis-Chlordane	-	ND
o,p'-DDD	-	4.04 (1)
p,p'-DDD	-	ND
cis-Nonachlor	-	0.04 (1)
p,p'-DDT	-	2.25 (1)
Heptachlor epoxide	-	ND
alpha-Endosulphan	-	ND
Dieldrin	-	ND
Endrin	-	0.05 (1)
Methoxychlor	-	ND
PCBs (as Aroclor 1254/1260)	-	562.5 (1)

1 Primary samples are samples collected as close as reasonably possible to the source of the contaminants and is representative of the levels of contaminants being generated.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 15: LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): SECONDARY[1] SOIL

Compound[3]	Concentration (ng/g)	
	Range	Mean[2]
HCB	ND-0.83	0.15 (12)
Heptachlor	ND	ND
Aldrin	ND	ND
o,p'-DDE	ND-1.43	0.13 (12)
trans-Nonachlor	ND-0.26	0.04 (12)
p,p'-DDE	ND-102.4	8.82 (12)
Mirex	ND	ND
alpha-BHC	ND-1.14	0.37 (12)
beta-BHC	ND	ND
gamma-BHC	ND-1.6	0.18 (12)
Oxychlordane	ND-6.6	0.79 (12)
trans-Chlordane	ND-0.56	0.14 (12)
cis-Chlordane	ND-1.05	0.21 (12)
o,p'-DDD	ND-11.66	1.17 (12)
p,p'-DDD	ND-47.8	4.18 (12)
cis-Nonachlor	ND-16.25	1.42 (12)
p,p'-DDT	ND-171.8	16.9 (12)
Heptachlor epoxide	ND-64.15	5.72 (12)
alpha-Endosulphan	ND-4.15	0.59 (12)
Dieldrin	ND-14.05	1.24 (12)
Endrin	ND-0.44	0.05 (12)
Methoxychlor	ND-3.31	0.58 (12)
PCBs (as Aroclor 1254/1260)	ND-385.3	39.17 (12)

1 Secondary samples were collected from areas directly impacted by the primary source and are an indication of the movement of the contaminants under study.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 16: LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): SECONDARY[1] SEDIMENT

Compound[3]	Concentration (ng/g)	
	Range	Mean[2]
HCB	0.05-0.28	0.156 (4)
Heptachlor	ND	ND
Aldrin	ND	ND
o,p'-DDE	ND-0.65	0.23 (4)
trans-Nonachlor	ND	ND
p,p'-DDE	ND-40.5	10.13 (4)
Mirex	ND	ND
alpha-BHC	ND-0.34	0.09 (4)
beta-BHC	ND	ND
gamma-BHC	ND	ND
Oxychlordane	ND-3.2	0.80 (4)
trans-Chlordane	ND-0.08	0.03 (4)
cis-Chlordane	ND-0.13	0.04 (4)
o,p'-DDD	ND-5.38	1.75 (4)
p,p'-DDD	ND-2.0	0.50 (4)
cis-Nonachlor	ND	ND
p,p'-DDT	ND-0.6	0.23 (4)
Heptachlor epoxide	ND-1.0	0.28 (4)
alpha-Endosulphan	ND	ND
Dieldrin	ND	ND
Endrin	ND	ND
Methoxychlor	ND-0.65	0.16 (4)
PCBs (as Aroclor 1254/1260)	ND-220	64.38 (4)

1 Secondary samples were collected from areas directly impacted by the primary source and are an indication of the movement of the contaminants under study.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 17: LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): SECONDARY[1] SHELLFISH

Compound[4]	Concentration (ng/g)	
	Range	Mean[2]
HCB	ND-0.10	0.04 (4)
Heptachlor	ND	ND
Aldrin	N/A[3]	N/A[3]
o,p'-DDE	ND-0.98	0.56 (4)
trans-Nonachlor	ND-0.79	0.30 (4)
p,p'-DDE	ND-0.60	0.36 (4)
Mirex	ND	ND
alpha-BHC	0.14-0.16	0.15 (4)
beta-BHC	ND-0.34	0.13 (4)
gamma-BHC	ND-0.04	0.01 (4)
Oxychlordane	ND-0.30	0.09 (4)
trans-Chlordane	ND-0.26	0.14 (4)
cis-Chlordane	ND-0.23	0.13 (4)
o,p'-DDD	ND-1.70	0.71 (4)
p,p'-DDD	ND-0.46	0.22 (4)
cis-Nonachlor	ND-0.20	0.07 (4)
p,p'-DDT	ND-0.99	0.49 (4)
Heptachlor epoxide	ND	ND
alpha-Endosulphan	ND-0.15	0.04 (4)
Dieldrin	ND-0.18	0.07 (4)
Endrin	ND	ND
Methoxychlor	ND	ND
PCBs (as Aroclor 1254/1260)	ND-35.5	13.88

1 Secondary samples were collected from areas directly impacted by the primary source and are an indication of the movement of the contaminants under study.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 This sample was not analyzed.

4 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 18: LEVELS OF ORGANOCHLORINE COMPOUNDS IN THE B.C. ENVIRONMENT (1990-91): SECONDARY[1] FISH

Compound[4]	Concentration (ng/g)	
	Range	Mean[2]
HCB	0.16-0.34	0.25 (2)
Heptachlor	ND	ND[3]
Aldrin	N/A[3]	N/A
o,p'-DDE	ND	ND
trans-Nonachlor	0.18-0.64	0.41 (2)
p,p'-DDE	1-5.9	3.45 (2)
Mirex	ND	ND
alpha-BHC	0.06-0.36	0.21 (2)
beta-BHC	ND	ND
gamma-BHC	0.03-0.14	0.09 (2)
Oxychlordane	ND-0.17	0.09 (2)
trans-Chlordane	0.18-0.22	0.2 (2)
cis-Chlordane	0.22-0.36	0.29 (2)
o,p'-DDD	ND-0.41	0.21 (2)
p,p'-DDD	0.27-1.7	0.99 (2)
cis-Nonachlor	ND-0.27	0.14 (2)
p,p'-DDT	ND-1.6	0.8 (2)
Heptachlor epoxide	ND	ND
alpha-Endosulphan	ND-0.07	0.04 (2)
Dieldrin	0.07-0.54	0.31 (2)
Endrin	ND	ND
Methoxychlor	ND	ND
PCBs (as Aroclor 1254/1260)	8.1-8.5	8.3 (2)

1 Secondary samples were collected from areas directly impacted by the primary source and are an indication of the movement of the contaminants under study.

2 Numbers in parentheses refer to the number of samples (N) used to calculate the mean.

3 This sample was not analyzed.

4 HCB - Hexachlorobenzene; DDE - Dichloro-2,2-bis (4 chlorophenyl) ethylene; BHC - Benzenehexachloride; DDD - Dichlorodiphenyldichloroethane; DDT - Dichlorodiphenyltrichloroethane; PCBs - Polychlorinated Biphenyls.

TABLE 19: NATIONAL/INTERNATIONAL COMPARISONS OF DIOXIN/FURAN LEVELS: SOILS

Country	Emission Type	Concentration	Reference
U.K.	Urban soils	TCDD[2] 8.5-160 pg/g TCDF[3] 29-950 pg/g	Creaser et al. 1990
Sweden	Urban soils	Total TEQ 13 - 49 pg/g	Broman et al. 1990
Sweden	Rural soils	Total TEQ 9 - 32 pg/g	Broman et al. 1990
USA	Soils from Manufacturing Site	TCDD 950 -2280 ppb TCDF 8 - 167 ppb	Umbriet 1986
UK	Rural Soils	TCDD 1-7 pg/g TCDF 3-50 pg/g	Stenhouse and Badsha 1990
Germany	Contaminated Site	TCDD 0.9-874 ppb	Sievers and Friesel 1989
USA	Soils near generating station	Total TCDF N.D. - 1.2 ppt[1] Total TCDD N.D.	Reed et al. 1990
USA	Urban Soils	TCDD (new chemical plant) ND - 0.59 ppb 0.1 - 10 ppt	Nestrick et al. 1986
Canada	Urban Soils	Total PCDD/F 0.38-1.82 ng/g	McLaughlin and Pearson 1985
Canada	Remote (Rural)	Total PCDD/F ND-0.81 ng/g	McLaughlin and Pearson 1985
Italy	Urban soils - collected within 1 km of a municipal incinerator	Total PCDD/F 0.01-0.48 ng/g	Berlincioni and di Domenico 1987
Denmark	Urban soils	Total PCDD's 4 - 7 ngm^{-2} 41 - 340 ng/kg	Nielsen and Lokke 1987
World Mean	Urban soils	Total PCDD/F 0.35 - 0.57 ng/g	Hattemer-Frey and Travis 1990 a,b
USA	Urban soils (background)	ND - 11.2 ppt	NATO 1988c

1 ppt = parts per trillion (pg/g).

2 Tetrachlorodibenzo-p-dioxin.

3 Tetrachlorodibenzofuran.

4 Polychlorinated dibenzo dioxins/furans.

TABLE 20: NATIONAL/INTERNATIONAL COMPARISONS OF DIOXIN/FURAN LEVELS: SEDIMENTS/SLUDGE

Country	Emission Type	Concentration	Reference
Canada	Sediments collected in the vicinity of B.C. Pulpmills	TCDF[2] (total) 1,570-4,521 ppt[1]	Mah et al. 1989
Canada	Suspended Solids collected downstream of pulpmills	TCDD[3] 11.5 pg/g	Merriman 1988
Sweden	Sediments collected from a river with no known dioxin inputs	TCDD N.D pg/g TCDF 4.9-5.6 pg/g	Kjeller et al. 1990
Sweden	Sediments collected from lakes receiving effluent from pulpmills	TCDD N.D.- 110 pg/g TCDF 41-810 pg/g	Kjeller et al. 1990
USA	Marine/Estuarine Sediments	TCDD N.D.- 57 pg/g TCDF 15 - 1,400 pg/g	Norwood et al. 1989
USA	Marine Sediments (Industrial Area) mid-1960s	<60 to 7,600 ppt	Tong et al. 1990
USA	Marine Sediments (Industrial Area) 1985 (+/- 1 year)	20-730 ppt	Tong et al. 1990
Canada	Sewage Sludge from Waste Water Treatment	TCDD N.D. TCDF N.D. - 25 ppt OCDD N.D. - 304 ppt	Ho and Clement 1990
Sweden	Sewage Sludge Primary	40 pg/g TEQ	Nåf et al. 1990
Sweden	Digested Sludge	31 pg/g TEQ	
Sweden	Sewage Sludge	TCDD N.D. TCDF - 5.3 pg/g OCDD - 3,400 pg/g	Rappe et al. 1989

1 ppt = parts per trillion (pg/g).

2 Tetrachlorodibenzofuran.

3 Tetrachlorodibenzo-p-dioxin.

4 Octachlorodibenzodioxin.

TABLE 21: NATIONAL/INTERNATIONAL COMPARISONS OF DIOXIN/FURAN LEVELS: INCINERATORS

Country	Emission Type	Concentration	Reference
Japan	Municipal Waste Incinerator	Flue Gas TCDD[1] > 50 ng/m^3 Flue Gas TCDF[2] > 50 ng/m^3	Yamamoto et al. 1989
Japan	Municipal Waste Incinerator	Flue Gas TCDD 14.3 ng/Nm^3 Fly Ash TCDD 6.46 ng/g	Hiraoka et al. 1990
USA	Medical Waste Incinerator	Flue Gas 363-11,811 ng/m^3	Lindner et al. 1990
USA	Municipal Waste Incinerators	Fly Ash Toxic Equivalents TCDD N.D.-18.1 ng/g	Goldfarb et al. 1990
USA	Municipal Waste Incinerators	Maximum Air Concentration Toxic Equivalents 2.1-48 fg/m^3	Travis and Hattemer-Frey, 1989
USA	Municipal Waste Incinerators	Flue Gas TCDD 3.65 fg/m^3	Mukerjee and Cleverly, 1987
Canada	Biomedical Waste Incineration	Flue Gas Dioxin Toxic Equivalents 0.9-52.4 ng/m^3	Ozvacic et al. 1990
Italy	Municipal Waste Incineration	Fly Ash Total TCDD 0.490-314 ng/g Total TCDF 0.120-69.6 ng/g	Bagnati et al. 1990
U.K.	Clinical/Municipal Incinerators	Fly Ash TCDD 0.0-90 ng/g TCDF 10-100 ng/g	Brown et al. 1990
Denmark	Municipal Incinerators	Flue Gas 11-473 ng/Nm^3	Manscher et al. 1990
Denmark	Hospital Incinerators	Flue Gas 2,910-3,490 ng/Nm^3	Manscher et al. 1990.
Japan/Canada/ Netherlands	Municipal Waste Incinerators	Fly Ash Total Dioxins 2-10 ng/g	Finkel et al. 1990
Sweden	Urban Air (background)	0.024 pg/m^3 TEQ	Näf et al. 1990
Canada			

[1] Tetrachlorodibenzo-p-dioxin.

[2] Tetrachlorodibenzofuran.

TABLE 22: NATIONAL/INTERNATIONAL COMPARISONS OF DIOXIN/FURAN LEVELS: FISH/MUSSELS/ VEGETATION

Country	Emission Type	Concentration	Reference
USA	Fish caught near a power station	TCDD[2] 1.0 - 3.0 ppt[1] TCDF[3] ND	Reed et al. 1990
USA	Vegetation collected in the vicinity of a power station	TCDF ND-1.9 ppt[1] TCDD ND-3.7 ppt	Reed et al. 1990
UK	Background vegetation	TCDD 0.3-9.7 ppt TCDF 1.2-11.2 ppt	Startin, Rose and Offen 1989

1 ppt = parts per trillion (pg/g).

2 Tetrachlorodibenzo-p-dioxin.

3 Tetrachlorodibenzofuran.

TABLE 23: NATIONAL/INTERNATIONAL COMPARISON OF ORGANOCHLORINE COMPOUND LEVELS: SEDIMENTS

Country	Emission Type	Concentration Range	Reference
Canada	Great Lakes	DDE[1] 2.2 - 130 ppb Mirex ND - 110 ppb HCB[2] 0.2 - 10 ppb PCB[3] 5.32 - 200 ppb	Environment Canada (DFO) 1991
USA	San Francisco Estuary System (Urban and Industrial)	DDE 0.21 - 1.32 ng/g PCB 5.71 - 255.26 ng/g	Phillips and Spies 1988
Canada	Lake Erie (Wheatley Harbour)	PCB 166.0 - 1176.8 µg/kg	Mudroch et al. 1989
Germany	Lippe River (Dorsten) (Mining Activity)	PCB 48.1 - 825 µg/kg	Friege et al. 1989
Netherlands	Rhine River Sediments	PCB 50 - 670 ng/g HCB 51.13 ng/g	Evers et al. 1988
Antarctica	McMurdo Sound Cinder Cone (docking facility, adjacent to dump site)	DDE <0.001 - 0.10 ng/g PCB <0.01 - 0.8 ng/g	Risebrough et al. 1990
New Zealand	Manukau Harbour	DDE 0.3 - 0.8 ng/g HCB (ng/g) <0.1 ng/g	Fox et al. 1988
Canada	Lake Ontario (Bottom Sediments)	HCB 27 - 32 ng/g Mirex 12 - 13 ng/g PCB 80 - 290 ng/g	Oliver et al. 1989

1 Dichloro-2,2-bis (4 chlorophenyl) ethylene.

2 Hexachlorobenzene.

3 Polychlorinated Biphenyls.

TABLE 24: NATIONAL/INTERNATIONAL COMPARISON OF ORGANOCHLORINE COMPOUND LEVELS : WATER

Country	Emission Type	Concentration	Reference
Germany	Lippe River (Dorsten) (Mining Activities)	PCB[2] (µg/L) <0.01 µg/L	Friege et al. 1989
Spain	Ebre River (Intensive Agriculture)	HCB[3] 2.7 - 3.6 pg/L	Grimalt et al.
USA	San Francisco Estuary Streams (Urban and Industrial)	DDE[4] ND - 61 ng/g	Phillips and Spies 1988
Canada	Lake Erie (Wheatley Harbour)	PCB 86.3 - 291.0 ng/L	Mudroch et al. 1989
Canada	Great Lakes	DDE ND - 0.139 ppt Mirex (ppt) ND HCB 0.018 - 0.26 ppt PCB 0.186 - 5.189 ppt	Environment Canada DFO 1991

[1] ppt = parts per trillion (pg/g).

[2] Polychlorinated Biphenyls.

[3] Dichloro-2,2-bis (4-chlorophenyl) ethylene.

TABLE 25: NATIONAL/INTERNATIONAL COMPARISON OF ORGANOCHLORINE COMPOUND LEVELS: BIOTA (fish, shellfish)

Country	Emission Type	Concentration	Reference
Canada	Lake Erie (Wheatley Harbour) FISH	PCB[2] 69.3 µg/kg	Mudroch et al. 1989
USA	San Francisco Estuary Streams (Urban and Industrial) MUSSELS	PCB (as Aroclor) ND-970 ng/g	Phillips and Spies 1988
Netherlands	Northern North Sea Cod Liver	HCB[3] 11-50 ug/kg	de Boer 1989
Finland	Kymijoki River MUSSELS	HCB 9-73 ng/g DDE[4] ND-33 ng/g PCB ND-1659 ng/g	Herve et al. 1988
India	South India Coastline MUSSELS	DDE 1.1-17 ng/g PCB - (ng/g) <1.0 - 7.1 ng/g	Ramesh et al. 1990
Nigeria	Nigerian Coast FISH	HCB 0.04 - 9.48 ng/g DDT[5] 0.15 - 18.60 ng/g PCB 11.0 - 225 ng/g	Oladele Osibanjo and Oluwakayode Bamgbose 1990
Nigeria	Nigerian Coast SHELLFISH	HCB ND - 0.80 ng/g DDT 4.73 - 152.0 ng/g PCB 37 - 287 ng/g	Oladele Osibanjo and Oluwakayode Bamgbose 1990
Finland	Baltic Sea HERRING MUSCLE	PCB (Aroclor 1254) 0.76 - 1.11 mg/kg DDE 0.14 - 0.22 mg/kg HCB 0.013 - 0.019 mg/kg	Hannu Haahti and Matti Perttilä 1988
Greece	Pagassitikos Gulf RED MULLET	PCB (Aroclor 1254) 2.5 - 375 µg/kg DDE 5.3 - 32.2 µg/kg	Satsmadjis et al. 1989
Spain	Valencia Coasts MUSSELS	HCB ND - 2.8 ng/g DDT 15 - 72 ng/g PCB 2.7 - 316 ng/g	Pastor et al. 1988
Spain	North Sea Area FLATFISH	PCB 0.30 - 2.3 µg/g HCB ND - 63 ng/g DDE 36 - 350 ng/g	Rainer Knickmeyer and Hans Steinhart 1990
India	Eastern Arabian Sea (Coast) *S. longiceps* FISH MUSCLE	DDE 14.9 - 28.8 ng/g	M.S. Shailaja and R. Sen Gupta 1989
Canada	Great Lakes FISH	PCB 0.64 - 3.39 ppm DDE 0.11 - 0.88 ppm Mirex ND - 0.20 ppm	Environment Canada (DFO) 1991

1 ppt = parts per trillion (pg/g).

2 Polychlorinated Biphenyls.

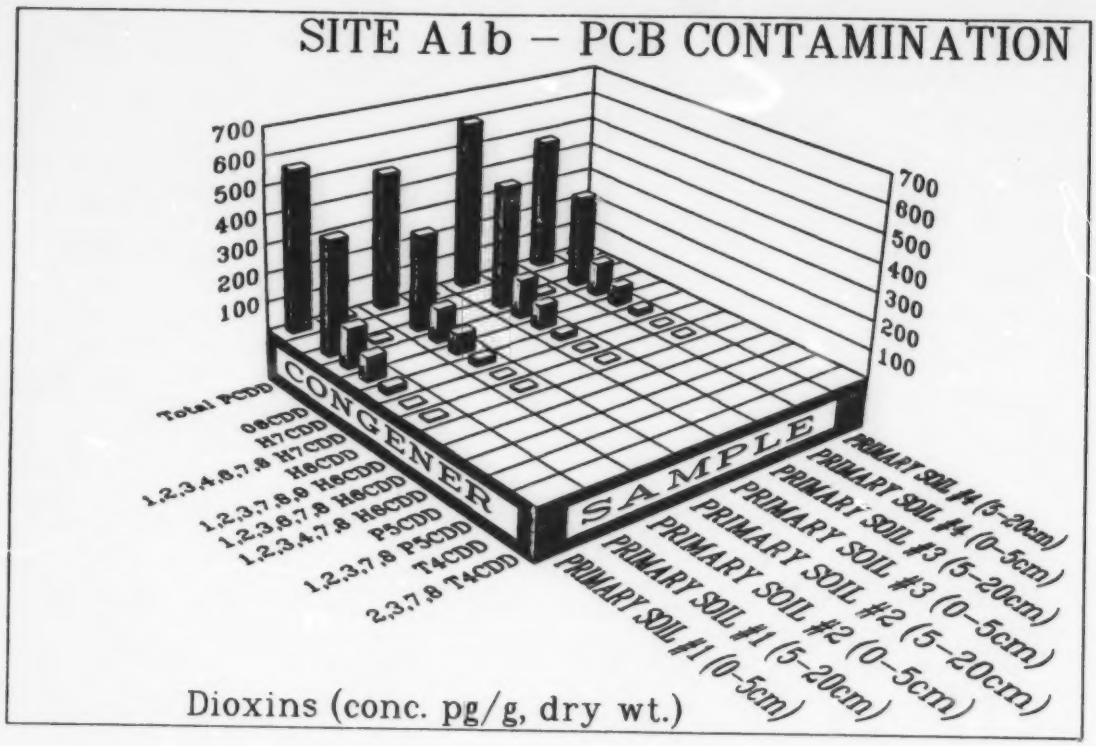
3 Hexachlorobenzene.

4 Dichloro-2,2-bis (4-chlorophenyl) ethylene.

5 Dichlorodiphenyltrichloroethane.

FIGURES 1-4

EXAMPLES OF FULL DIOXIN AND FURAN CONGENER PROFILES FOR TWO SITE: A1b AND A3a



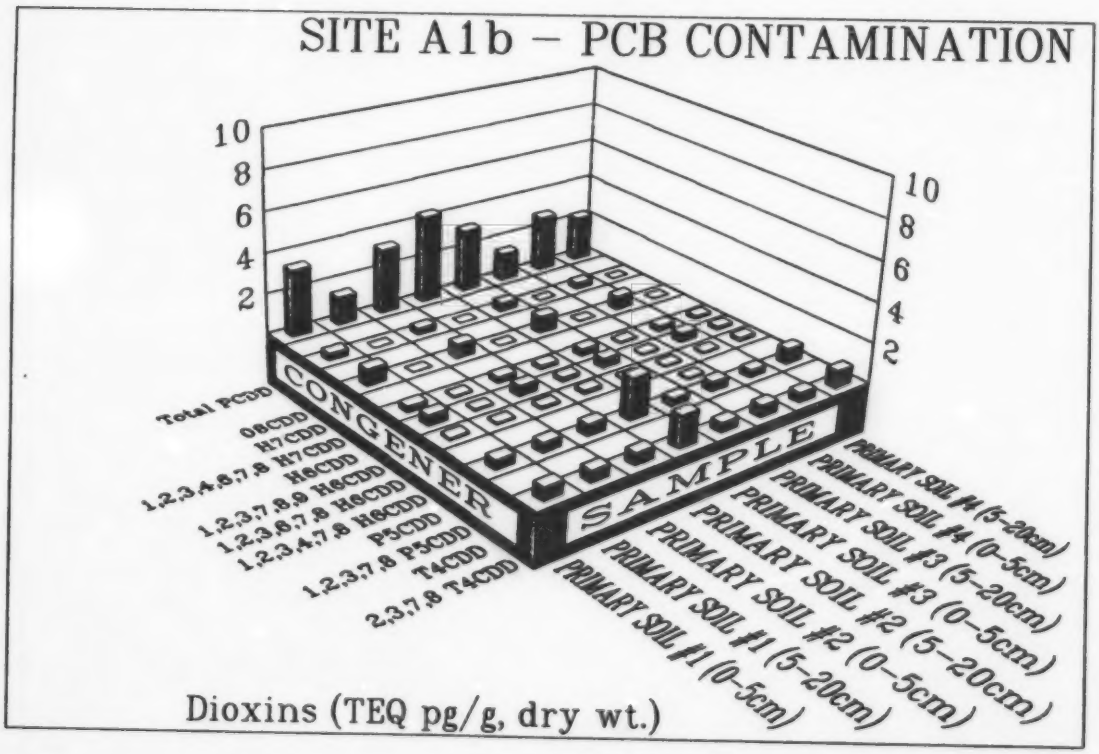
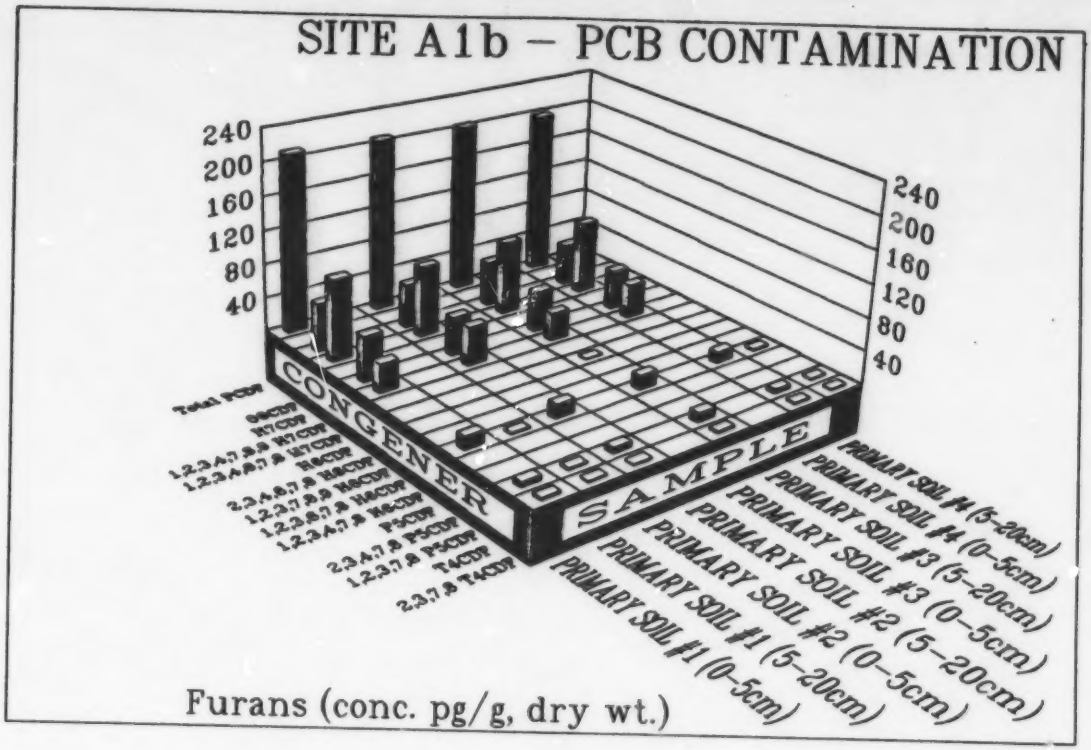


FIGURE 1 **Example of a full dioxin congener profile for a single site (concentration and TEQ): Site A1b.**



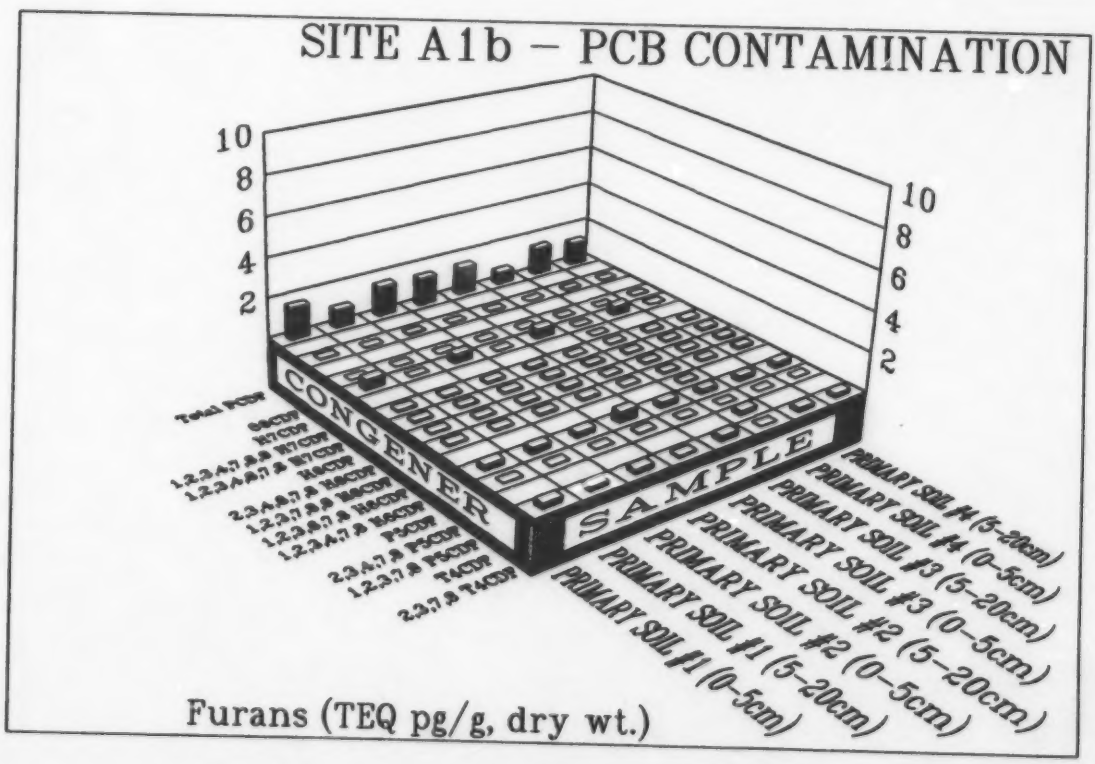
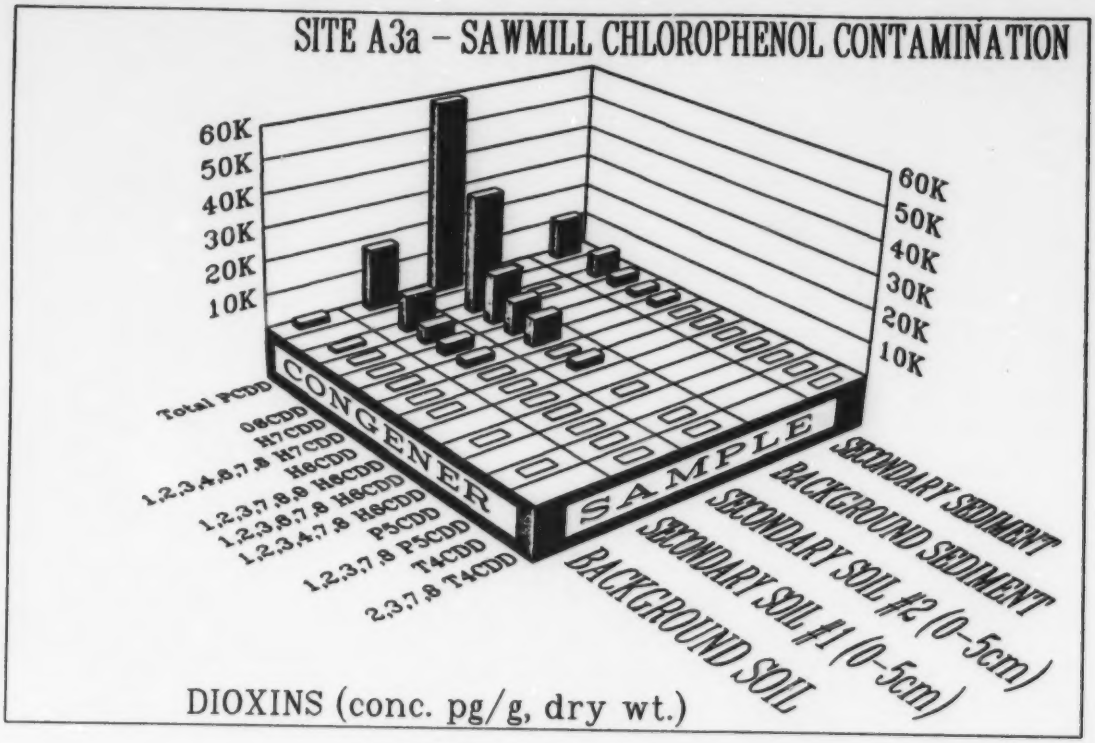


FIGURE 2 **Example of a full furan congener profile for a single site (concentration and TEQ): Site A1b.**



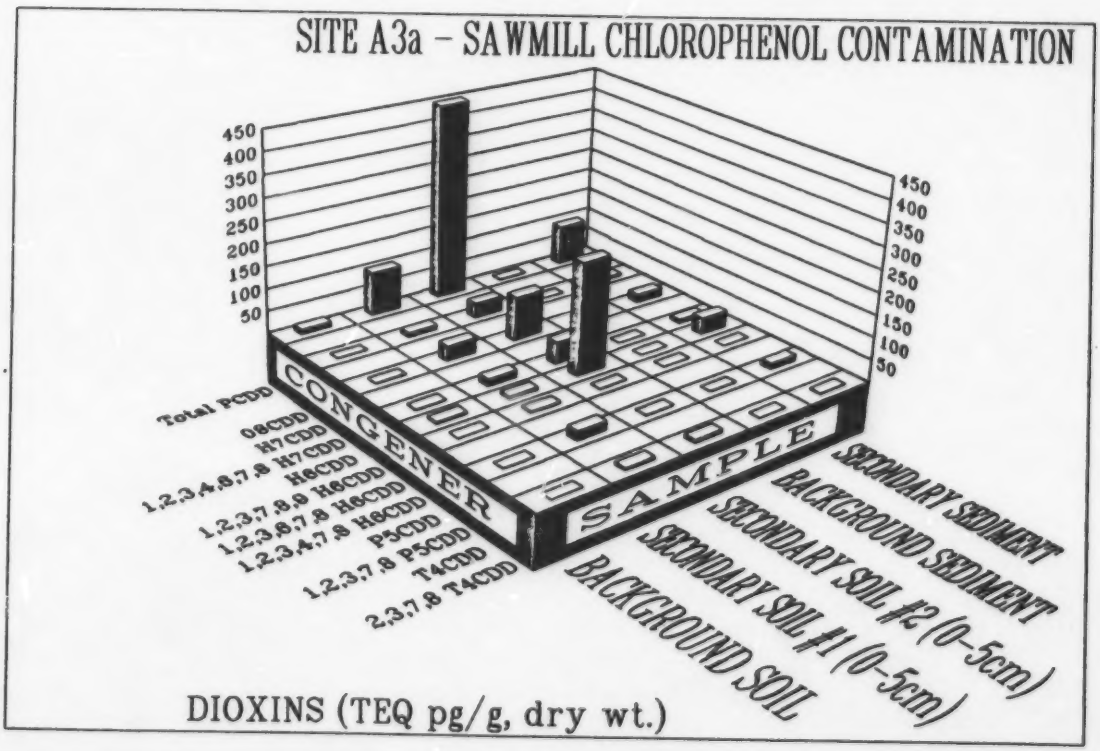
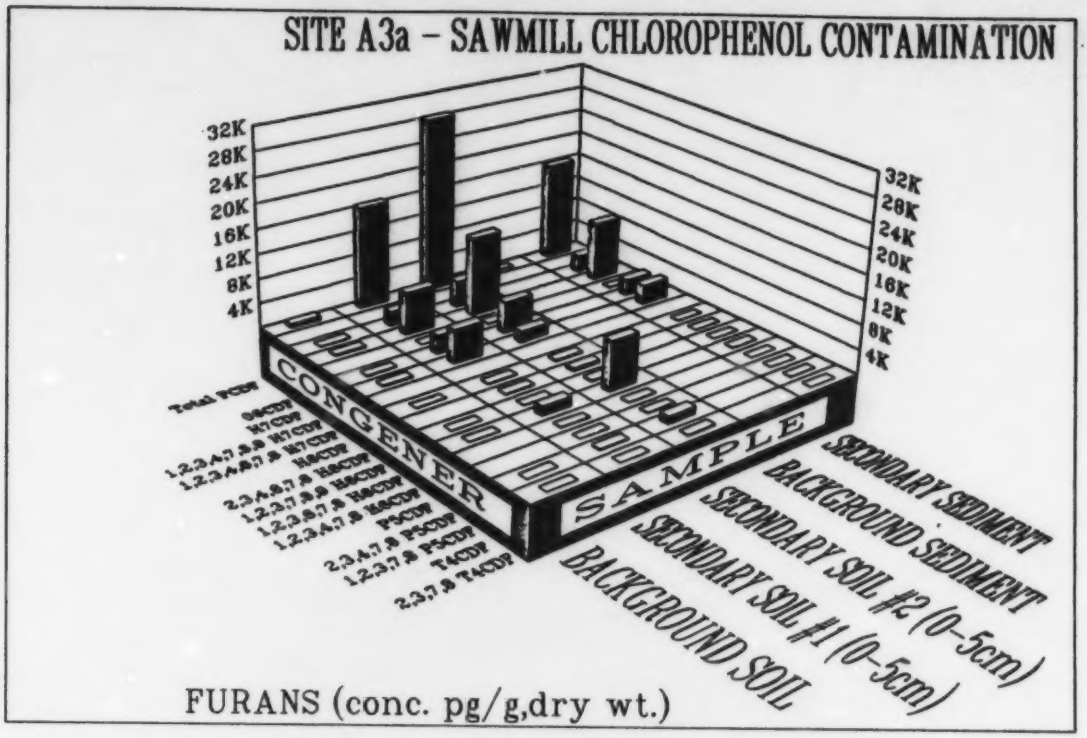


FIGURE 3 **Example of a full dioxin congener profile for a single site (concentration and TEQ): Site A3a.**



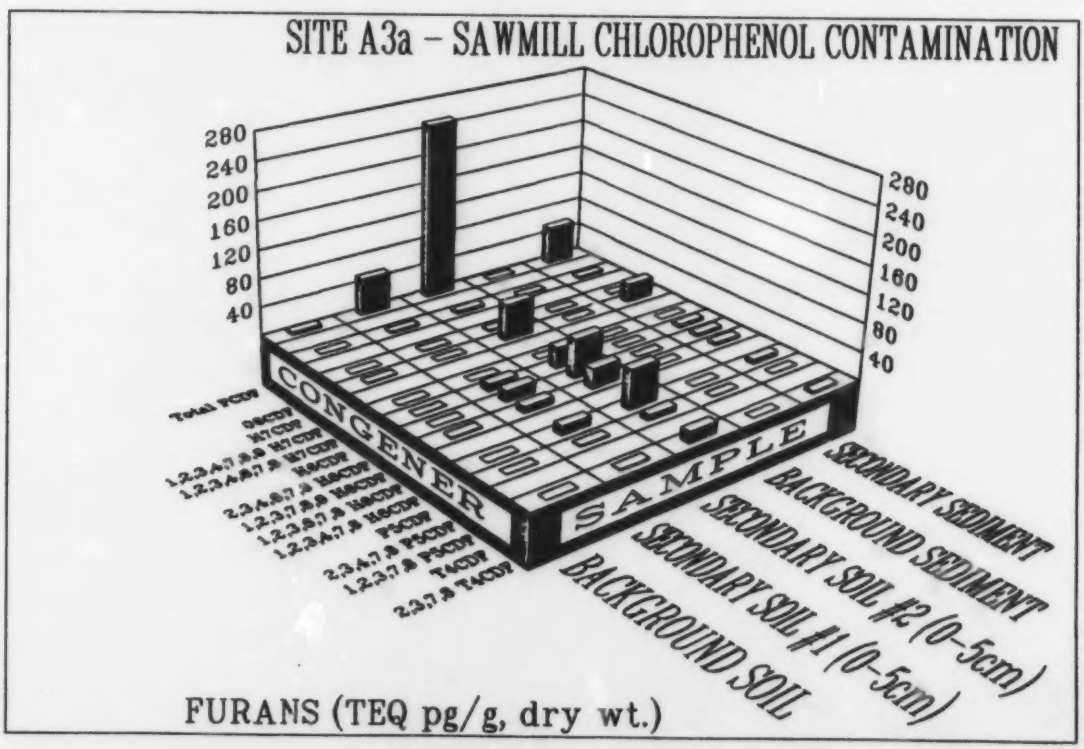


FIGURE 4 **Example of a full furan congener profile for a single site (concentration and TEQ): Site A3a.**

FIGURES 5-12

TOTAL 2,3,7,8-TC_4DD TEQ VALUES FROM SAMPLES COLLECTED FROM CHEMICAL SOURCES

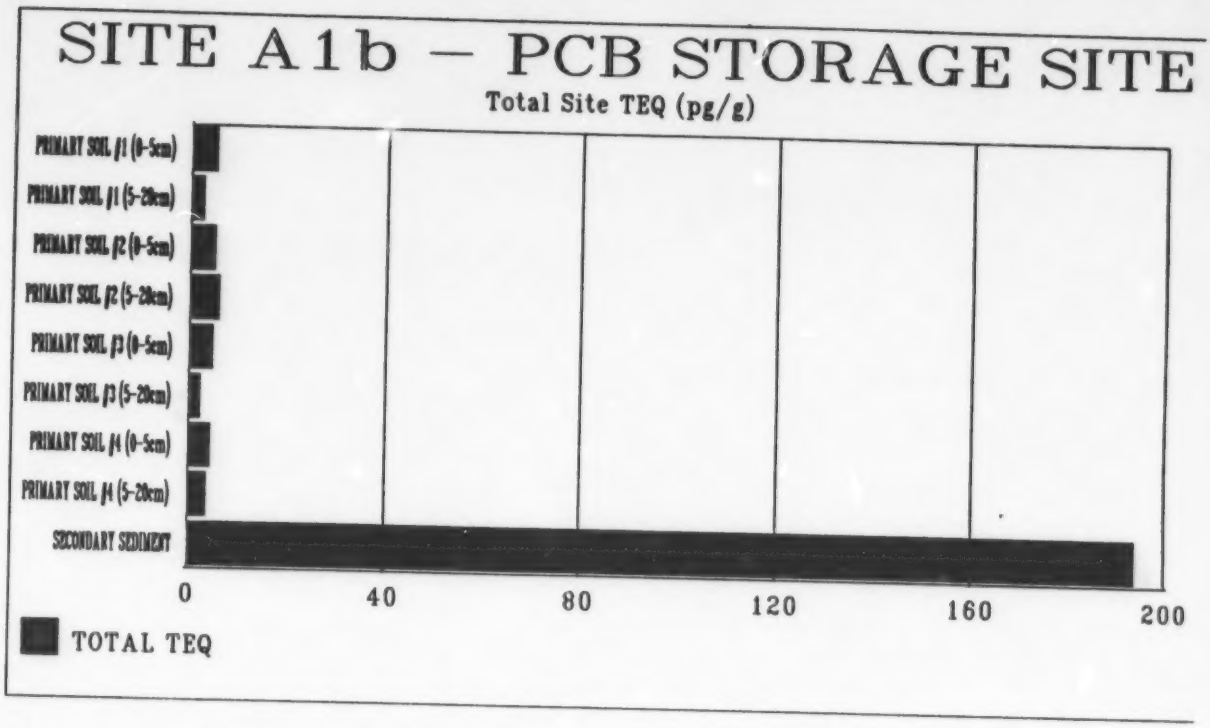


FIGURE 5 **Site A1b. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

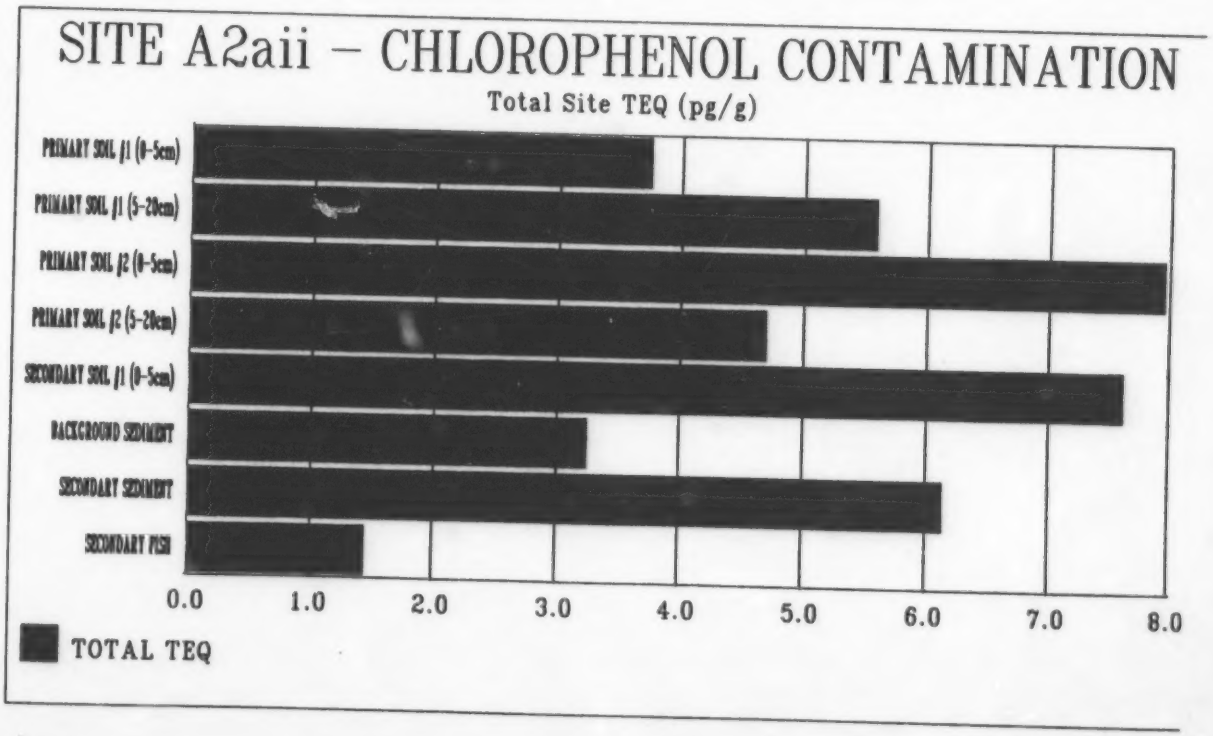


FIGURE 6 **Site A2aii. Dioxin and furan levels (2,3,7,8 TCDD-TEQs).**

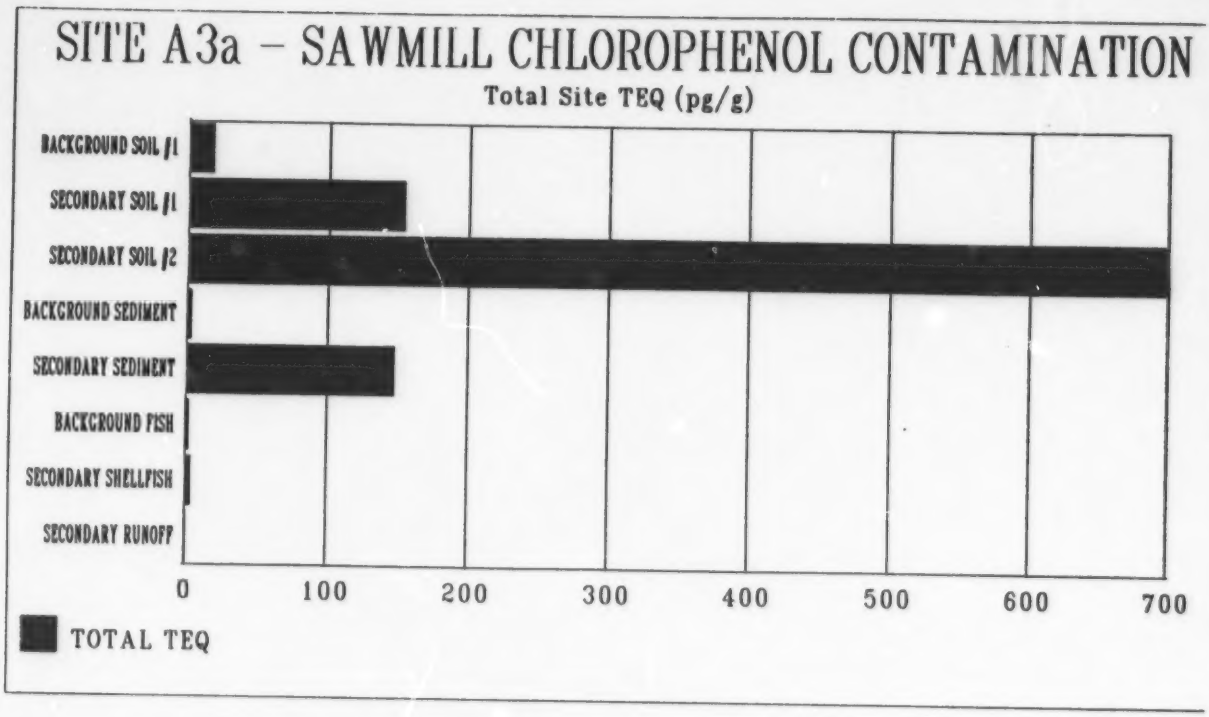


FIGURE 7 **Site A3a. Dioxin and furan levels (2,3,7,8 TCDD-TEQs).**

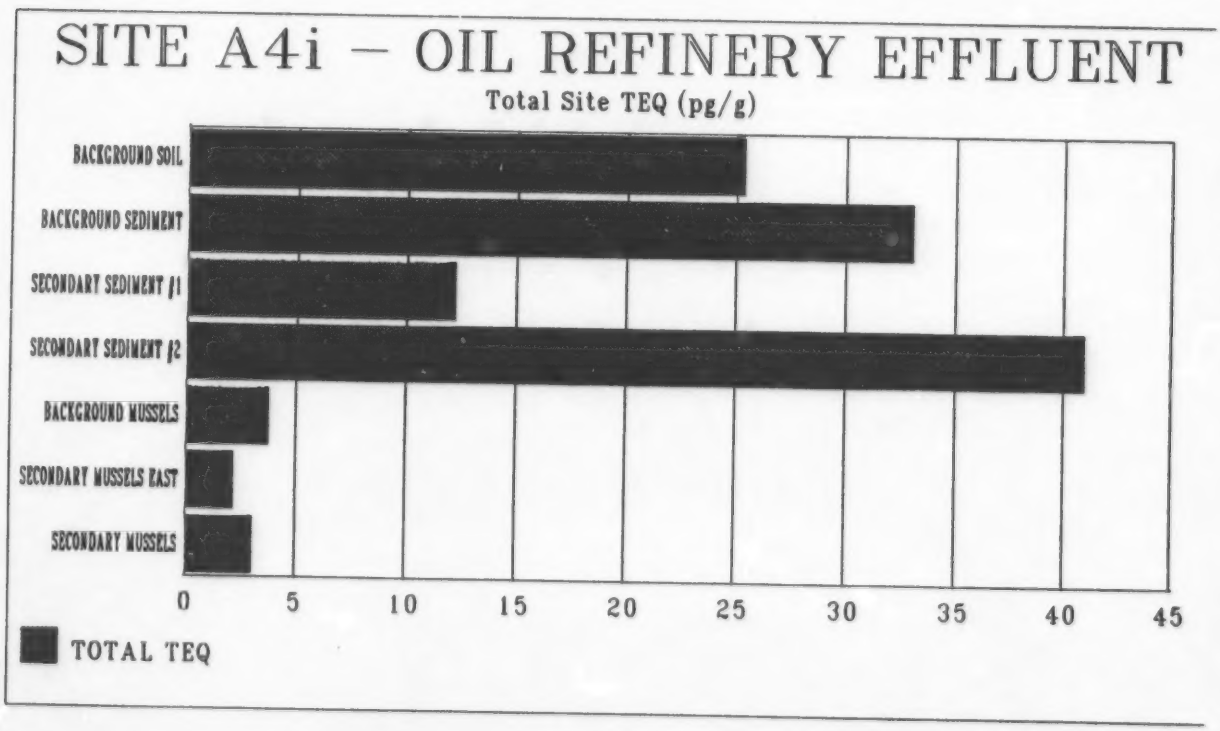


FIGURE 8 **Site A4i. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

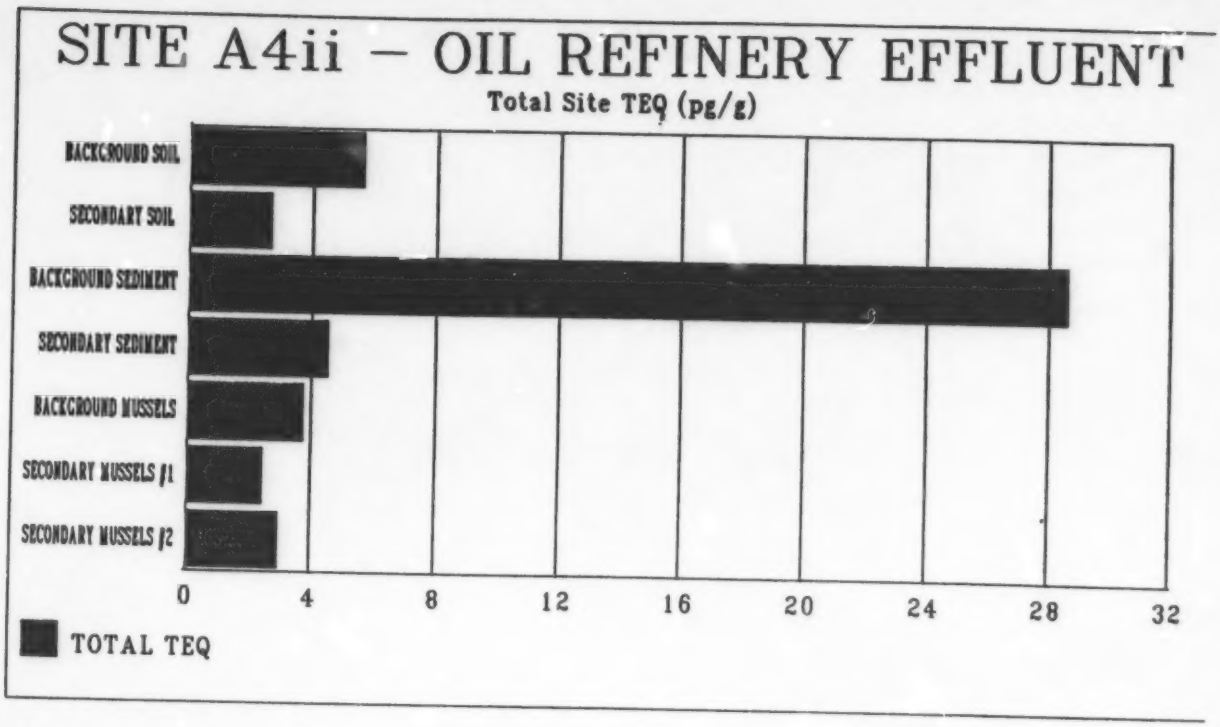


FIGURE 9 **Site A4ii. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

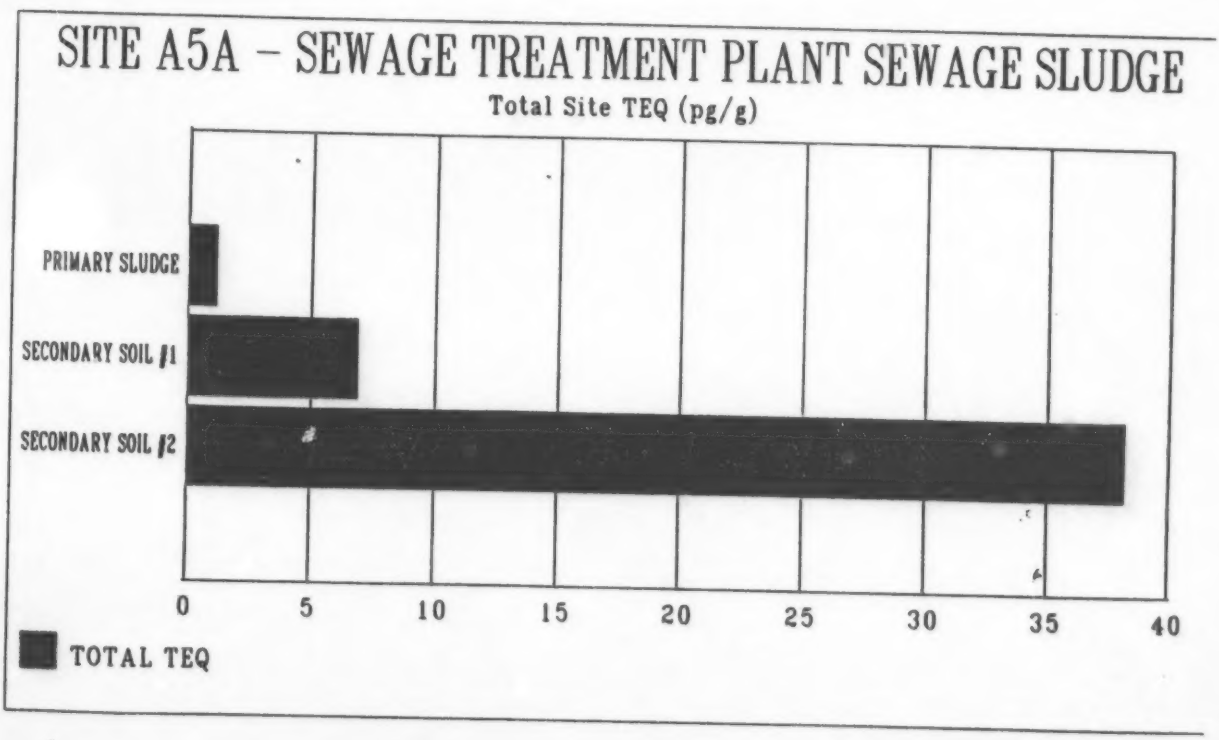


FIGURE 10 **Site A5a. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**
(Note: Primary sludge analysed as effluent and results expressed as pg/ml to facilitate comparison with pg/g.)

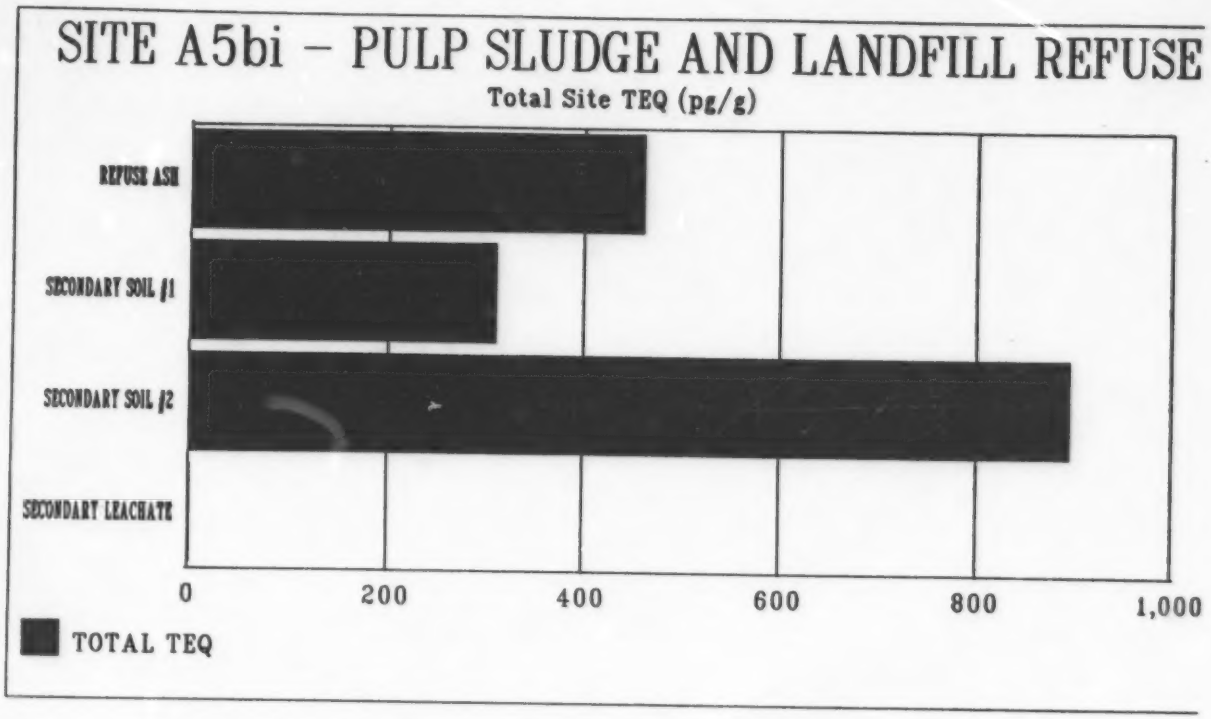


FIGURE 11 **Site A5bi. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Leachate expressed as pg/ml to facilitate comparison with pg/g.)**

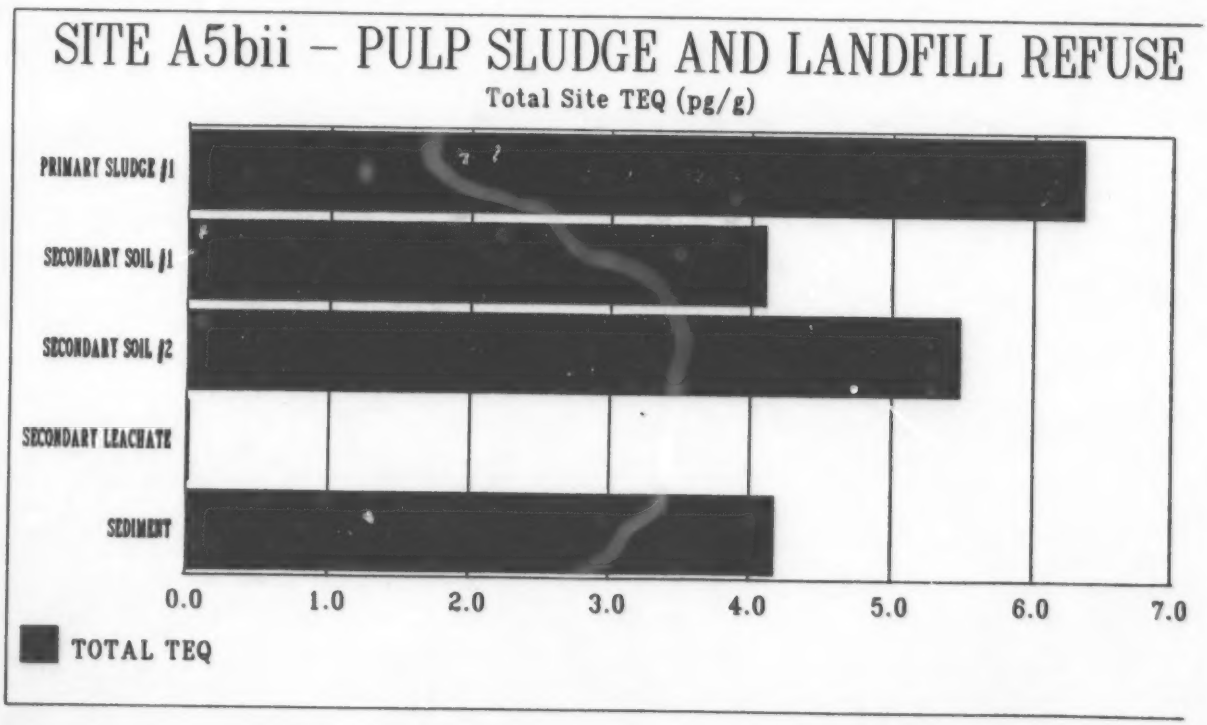


FIGURE 12 **Site A5bii. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Leachate expressed as pg/ml to facilitate comparison with pg/g.)**

FIGURES 13-30

TOTAL 2,3,7,8-TC_4DD TEQ VALUES FROM SAMPLES COLLECTED FROM COMBUSTION SOURCES

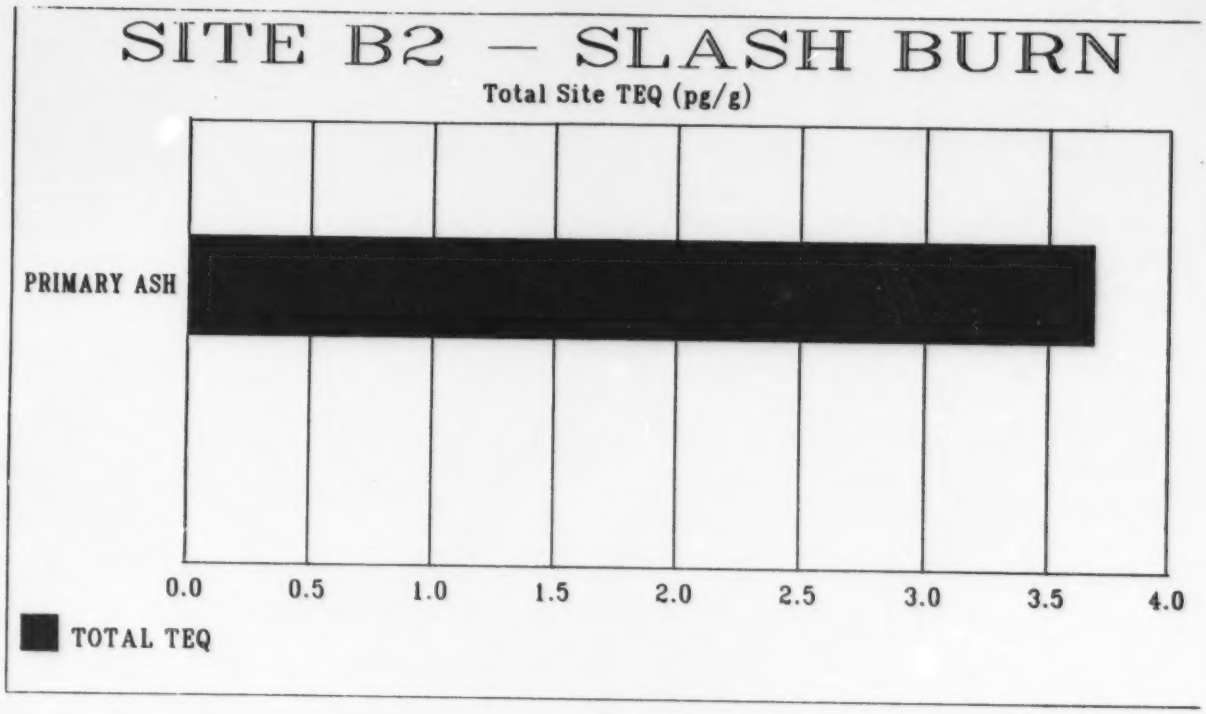


FIGURE 13 **Site B2. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

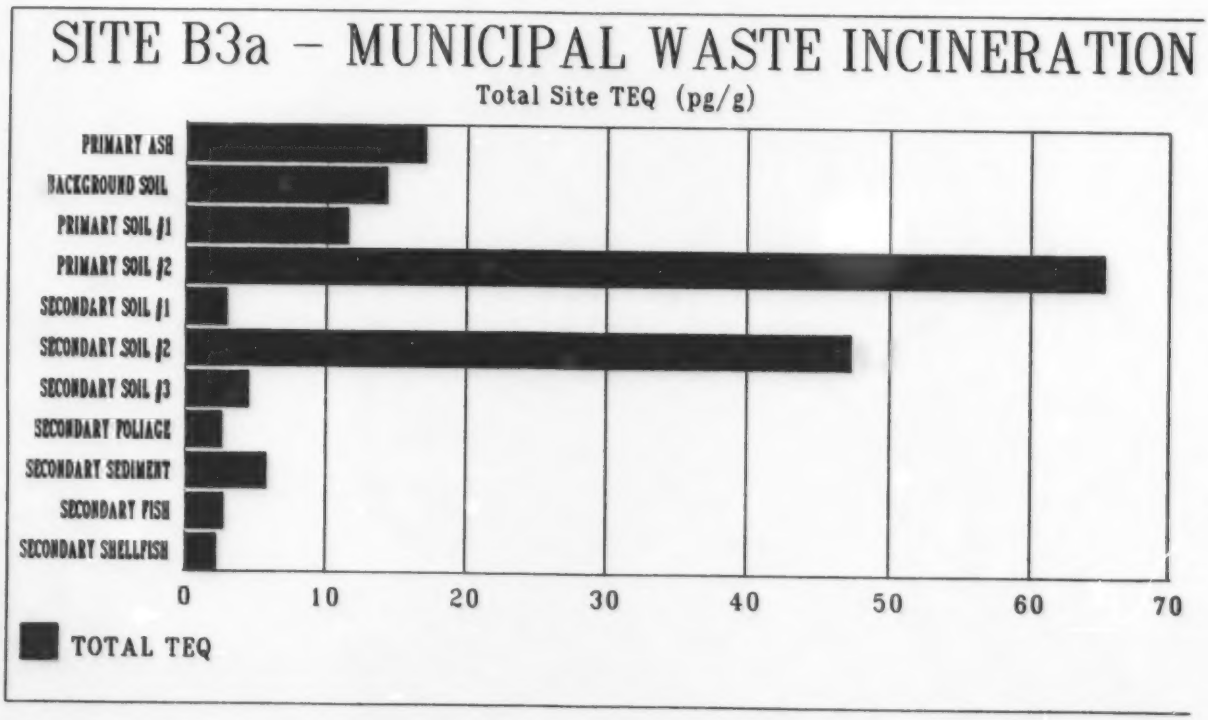


FIGURE 14 **Site B3a. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

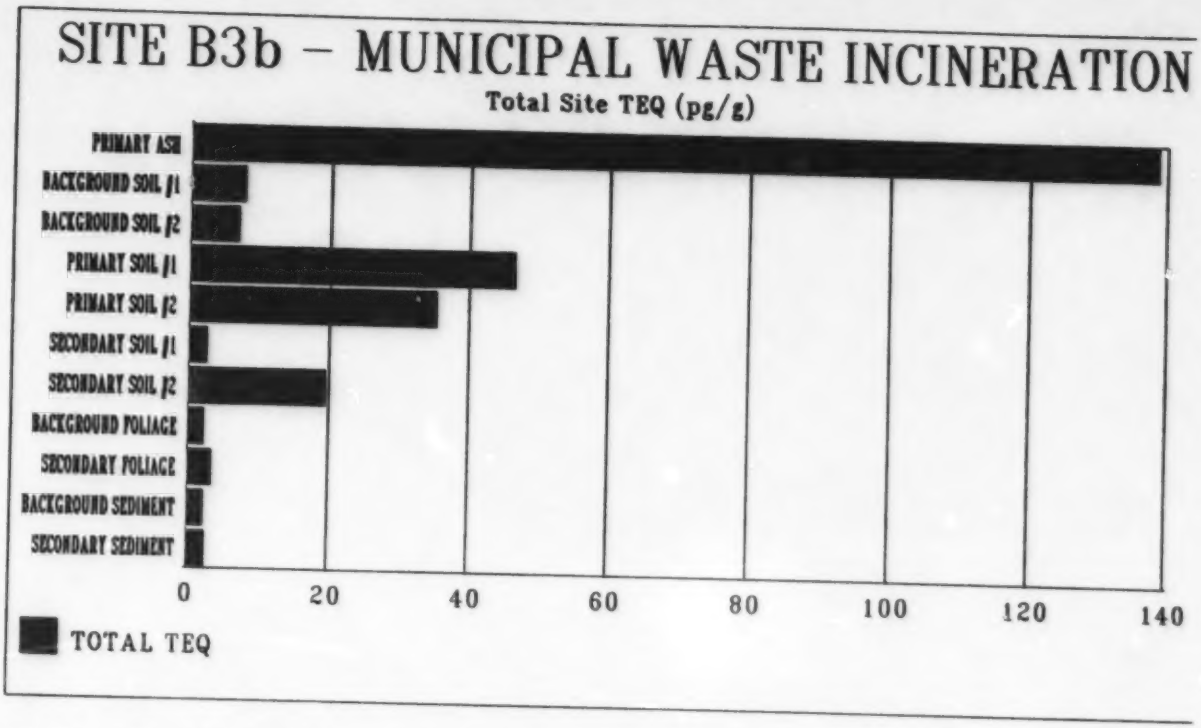


FIGURE 15 **Site B3b. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

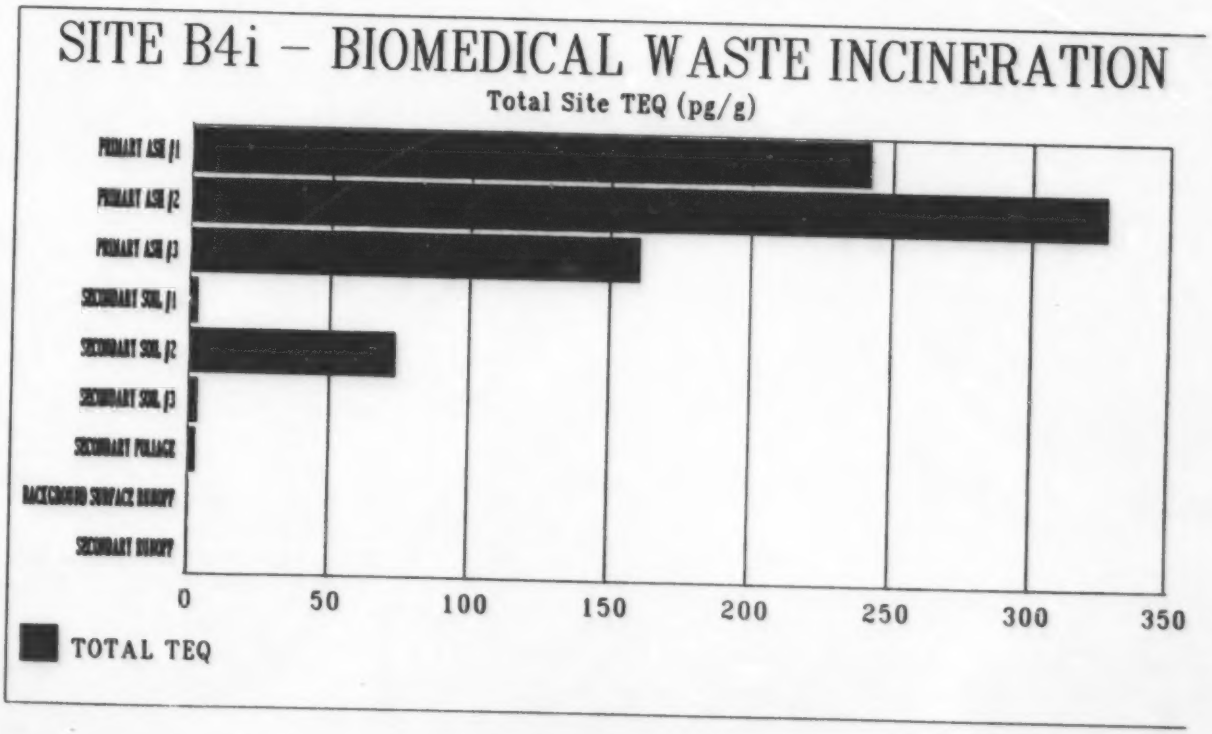


FIGURE 16 **Site B4i. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**
(Note: Runoff expressed as pg/ml to facilitate comparison with pg/g.)

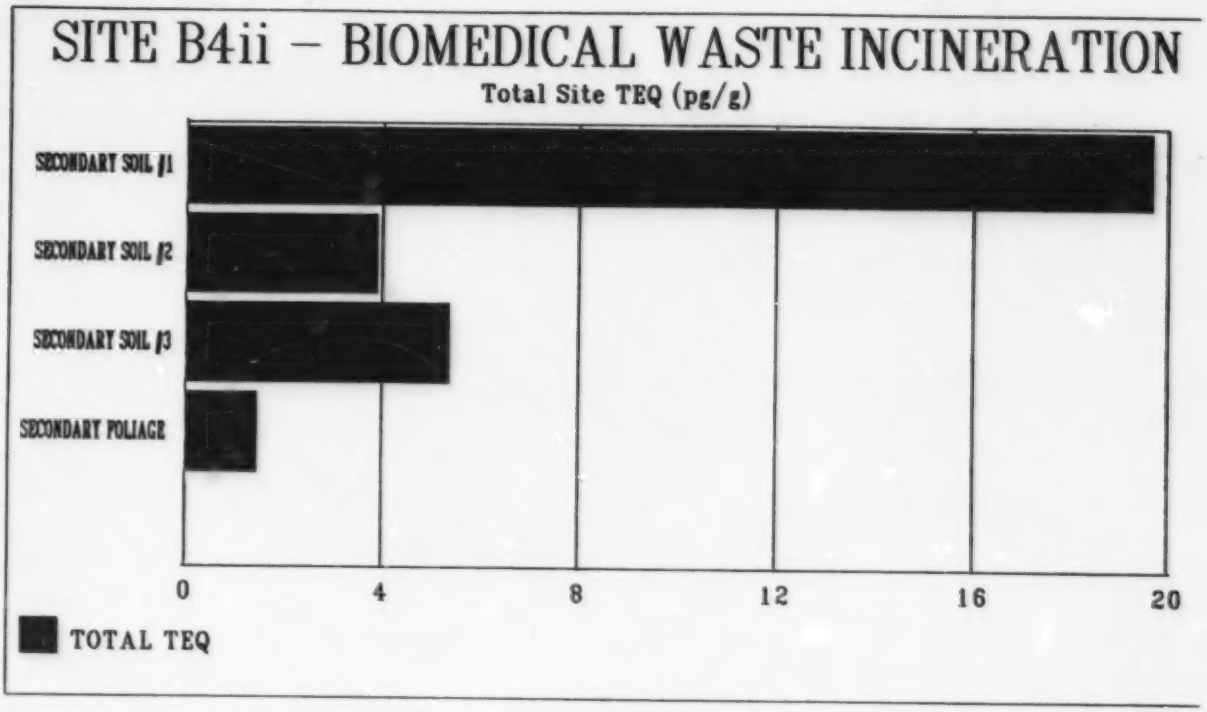


FIGURE 17 **Site B4ii. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Fly ash not included.)**

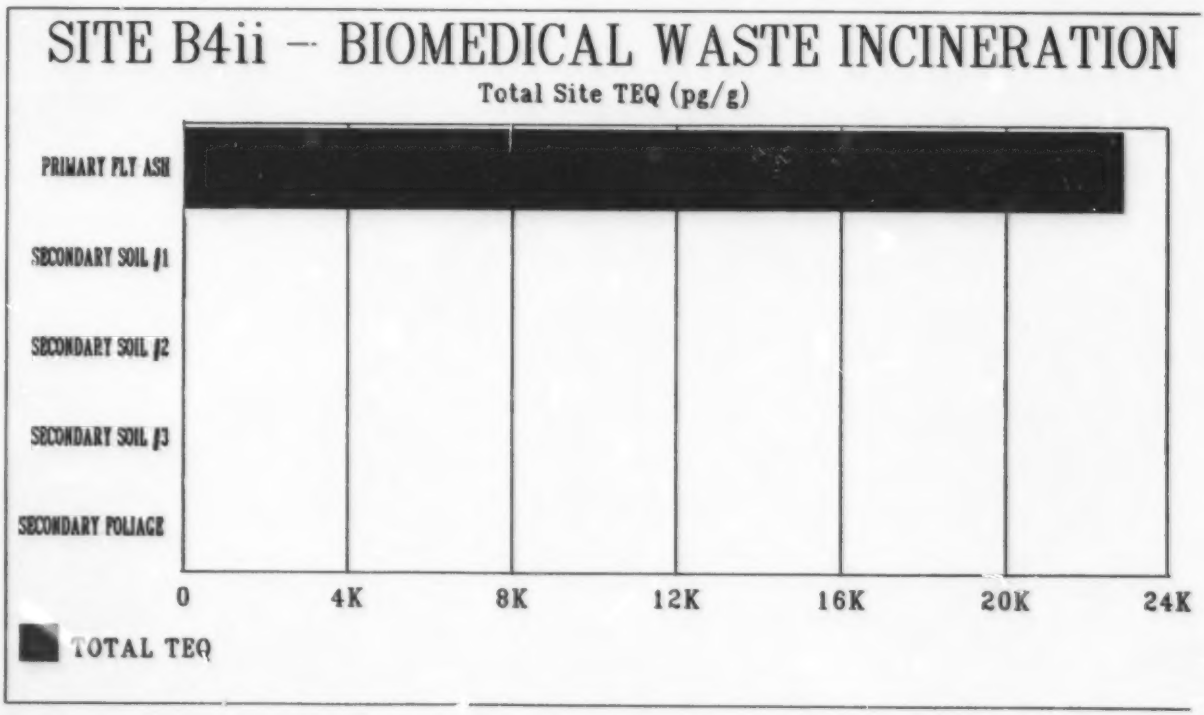


FIGURE 18 **Site B4ii. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Fly ash included.)**

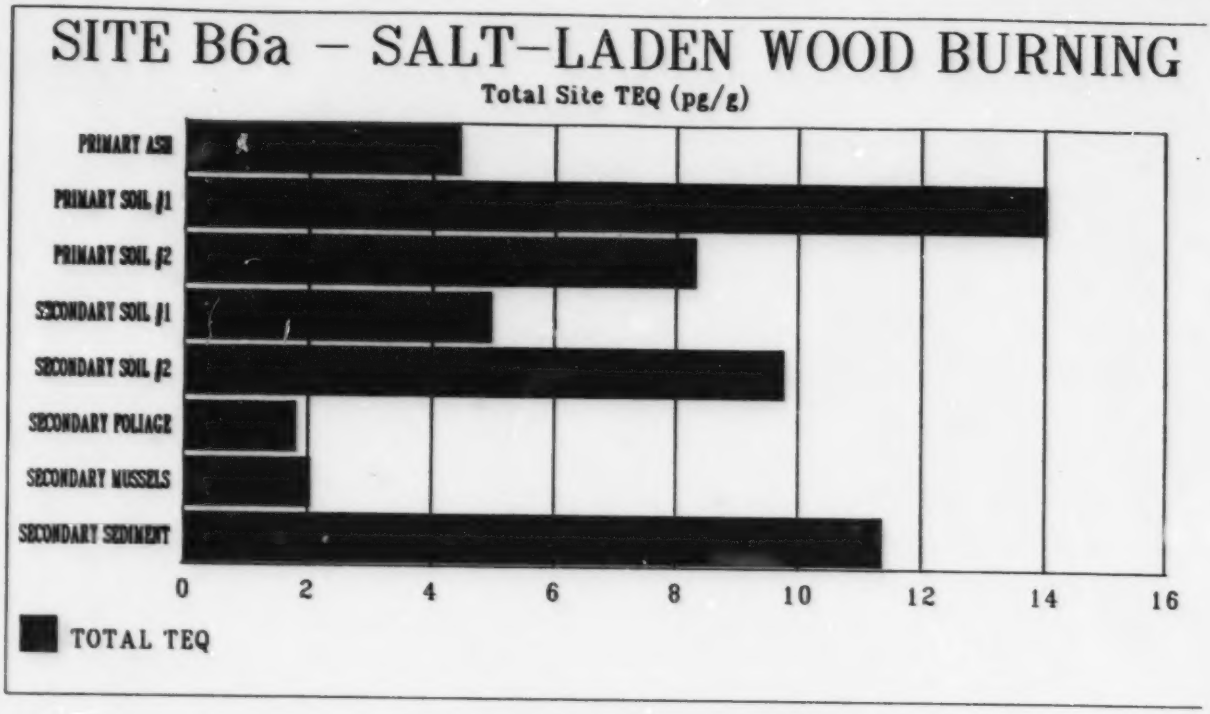


FIGURE 19 **Site B6a. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

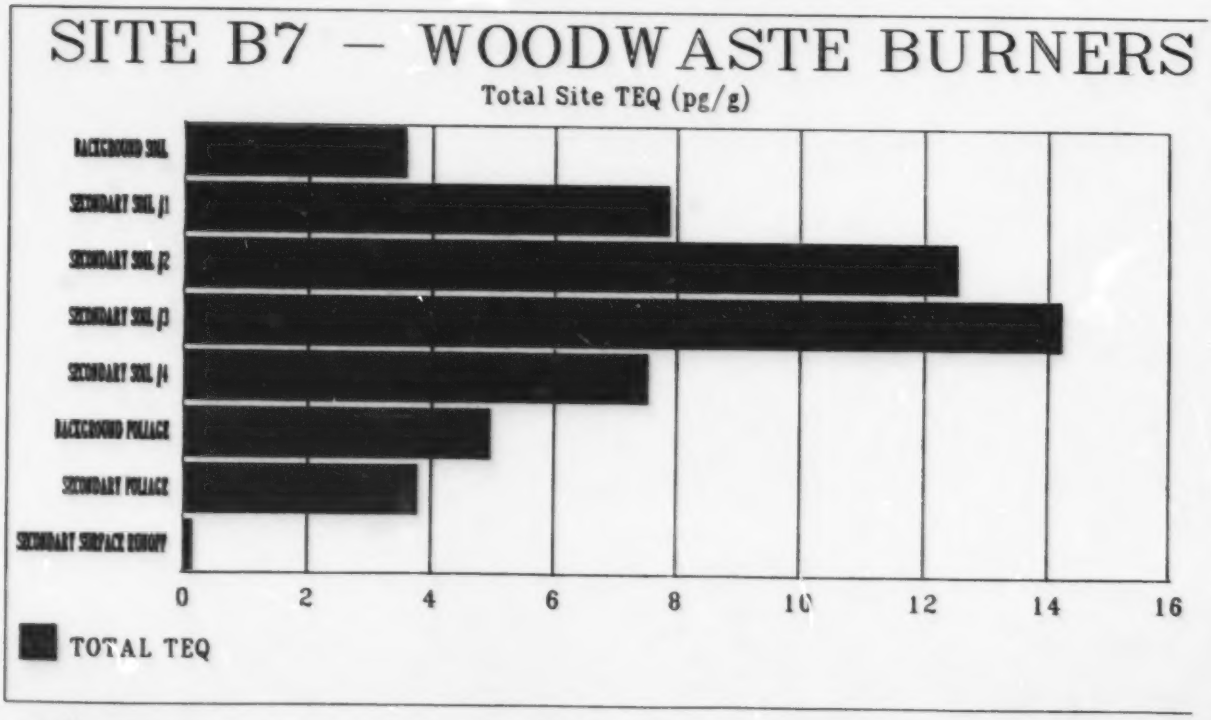


FIGURE 20 **Site B7. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**
(Note: Runoff expressed as pg/ml to facilitate comparison with pg/g.)

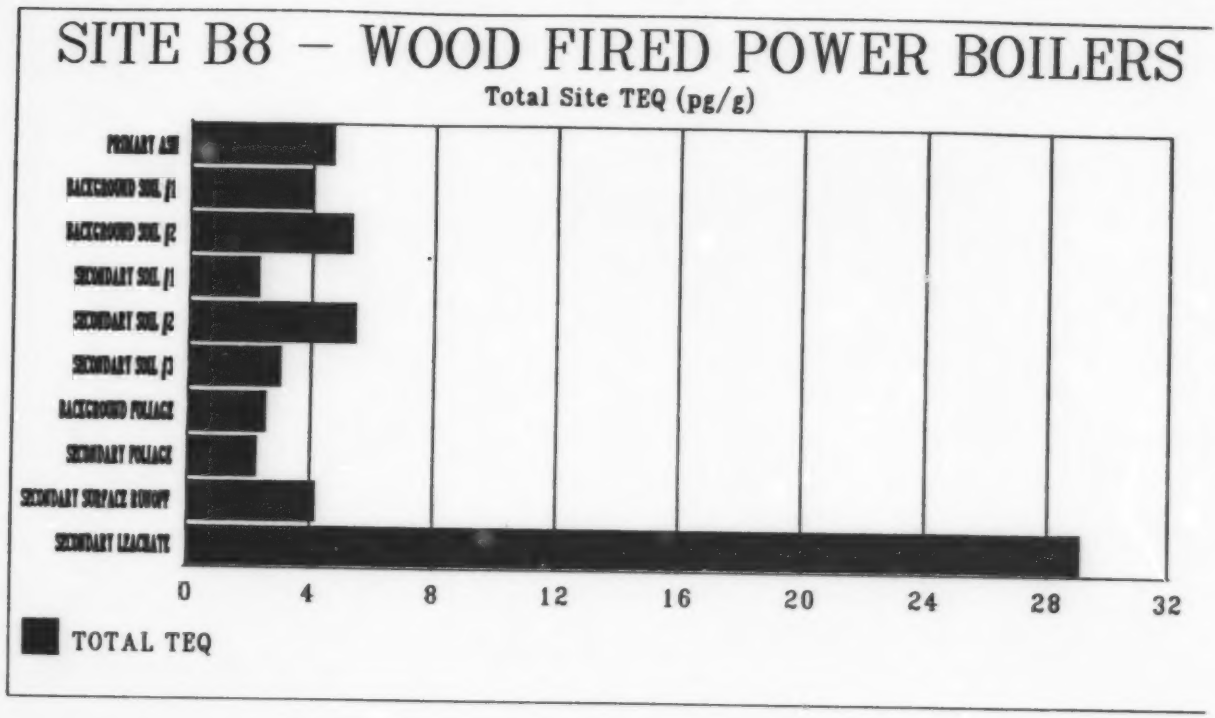


FIGURE 21 **Site B8. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Fly ash not included.)**

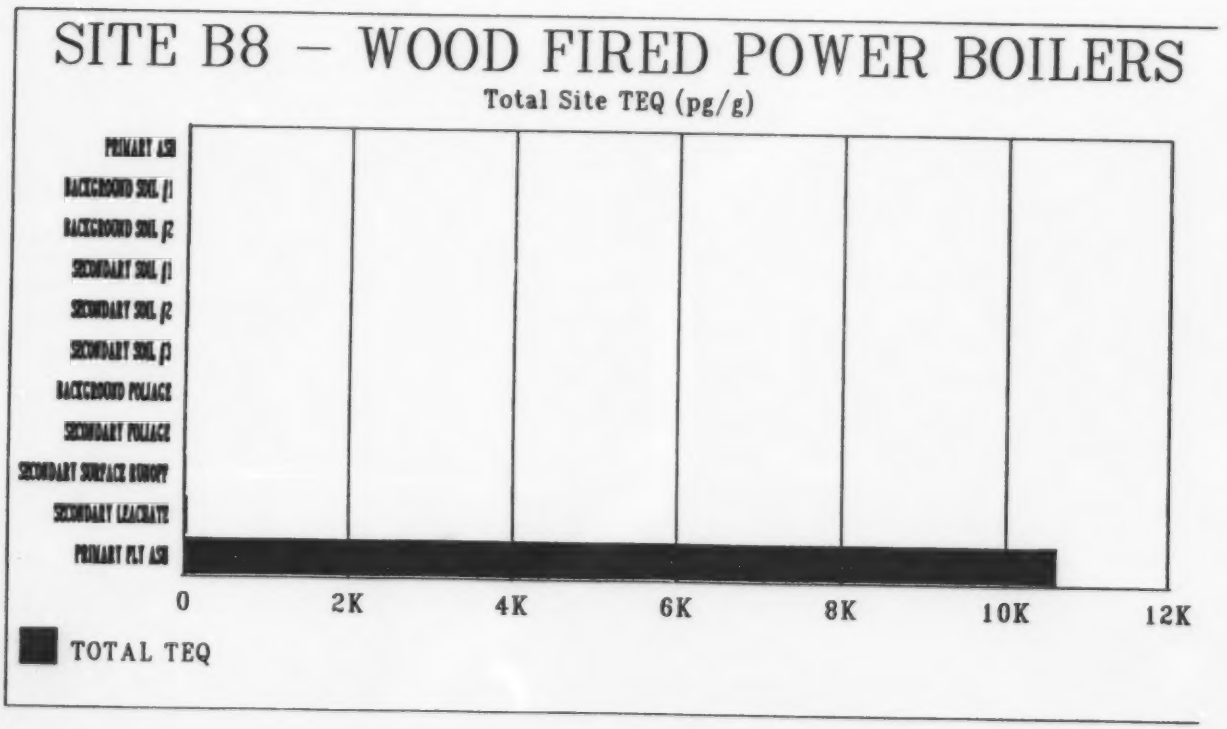


FIGURE 22 **Site B8. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Fly ash included; Leachate and runoff expressed as pg/ml to facilitate comparison with pg/g.)**

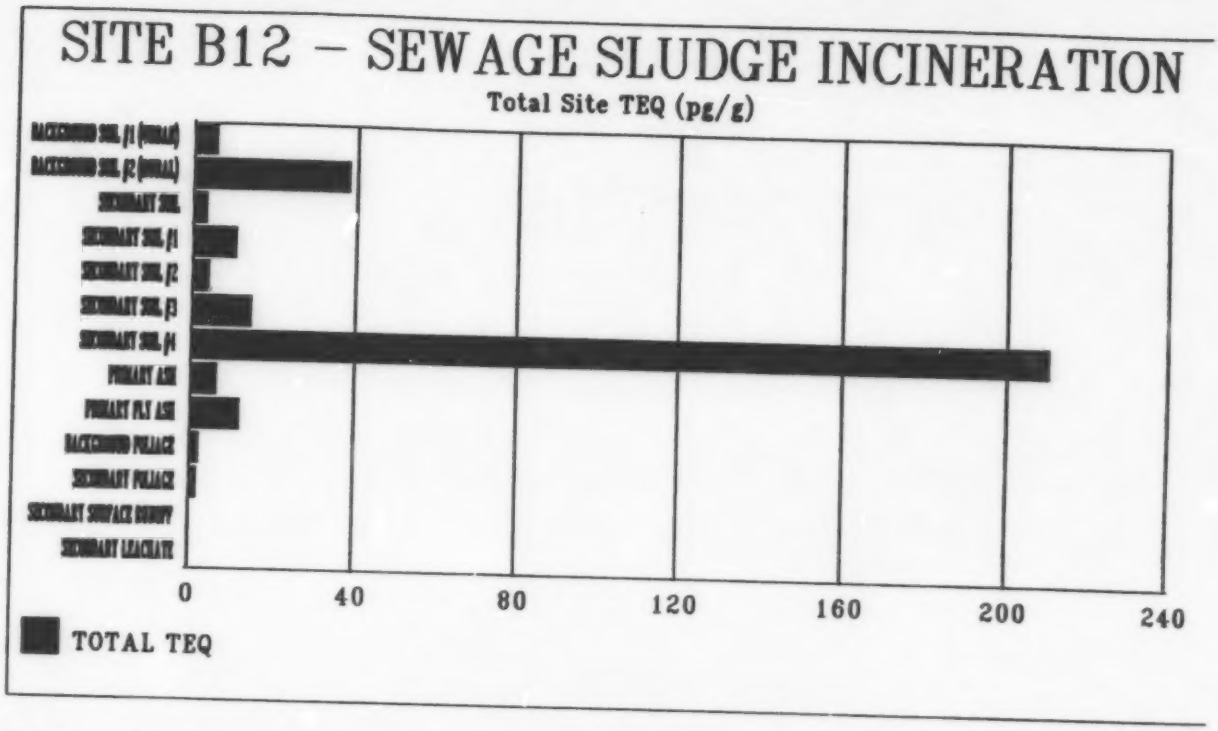


FIGURE 23 **Site B12. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Leachate and runoff expressed as pg/ml to facilitate comparison with pg/g.)**

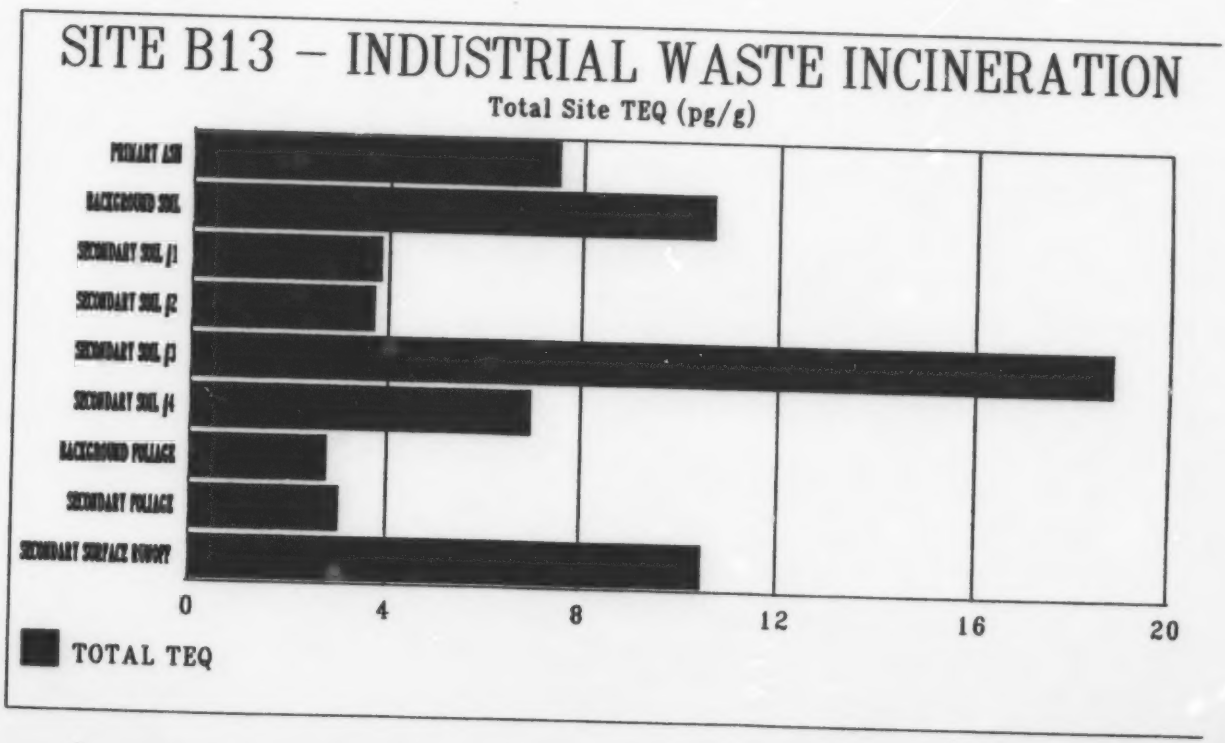


FIGURE 24 **Site B13. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Runoff expressed as pg/ml to facilitate comparison with pg/g.)**

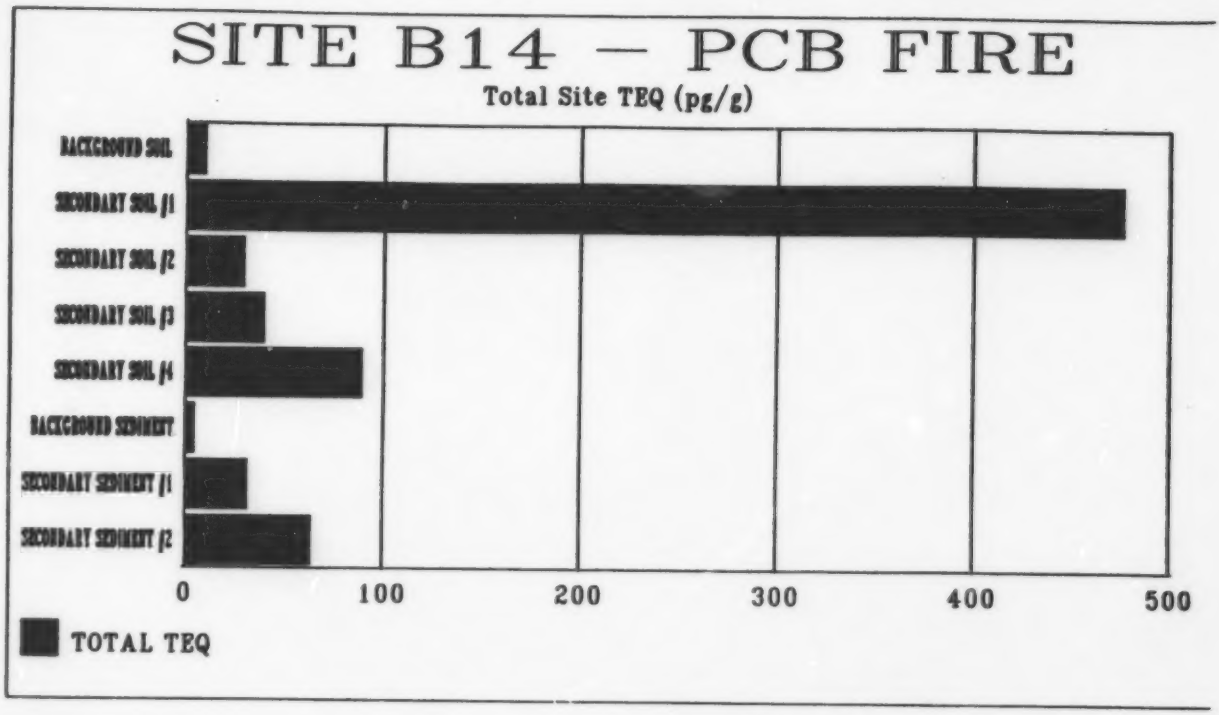


FIGURE 25 **Site B14. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

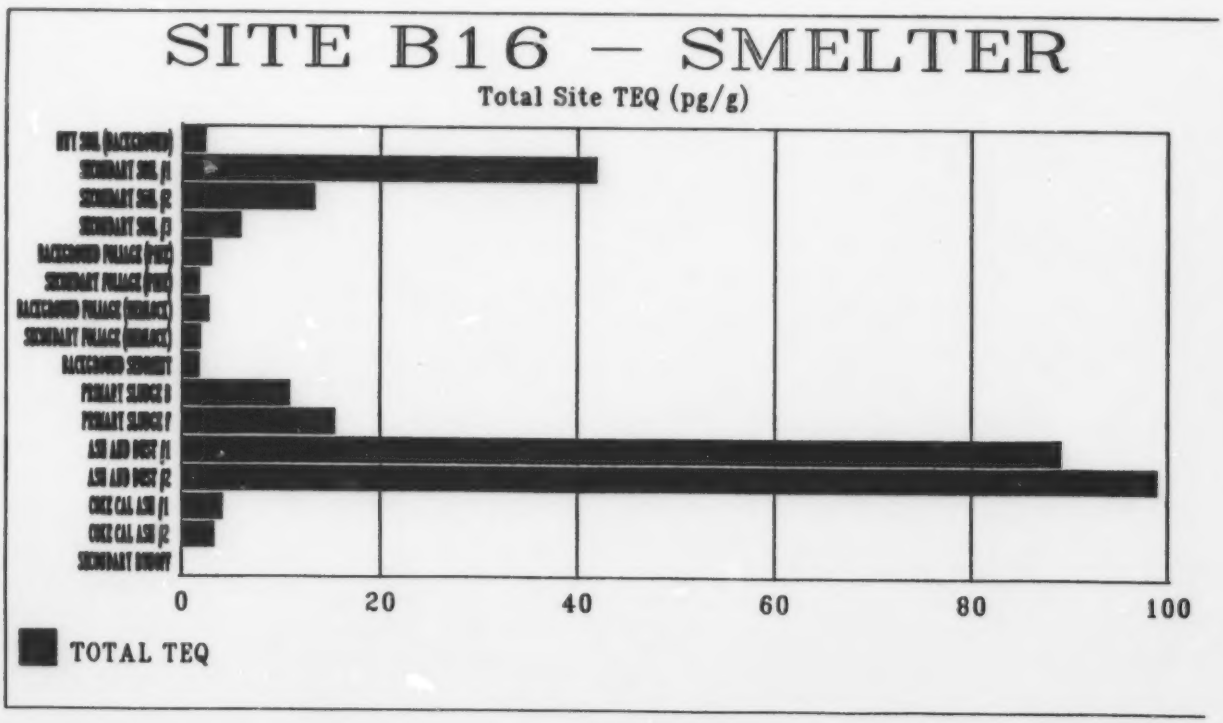


FIGURE 26 **Site B16. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**
(Note: Runoff expressed as pg/ml to facilitate comparison with pg/g.)

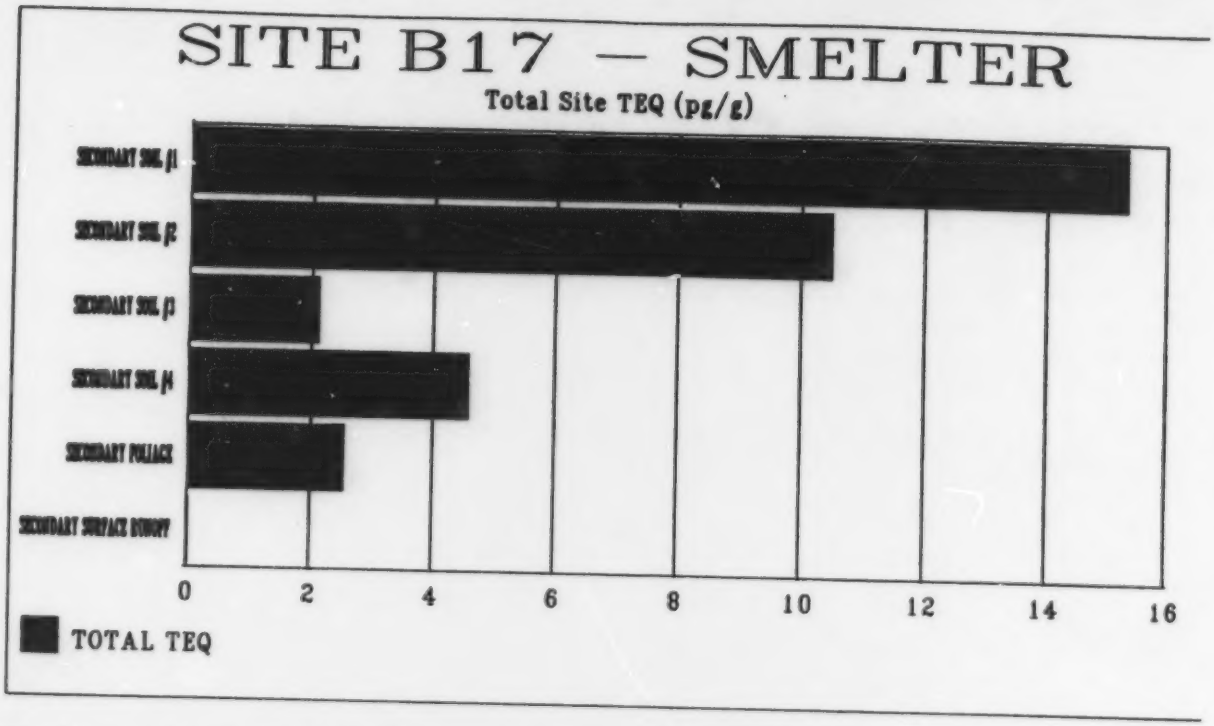


FIGURE 27 **Site B17. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Fly ash included.)**

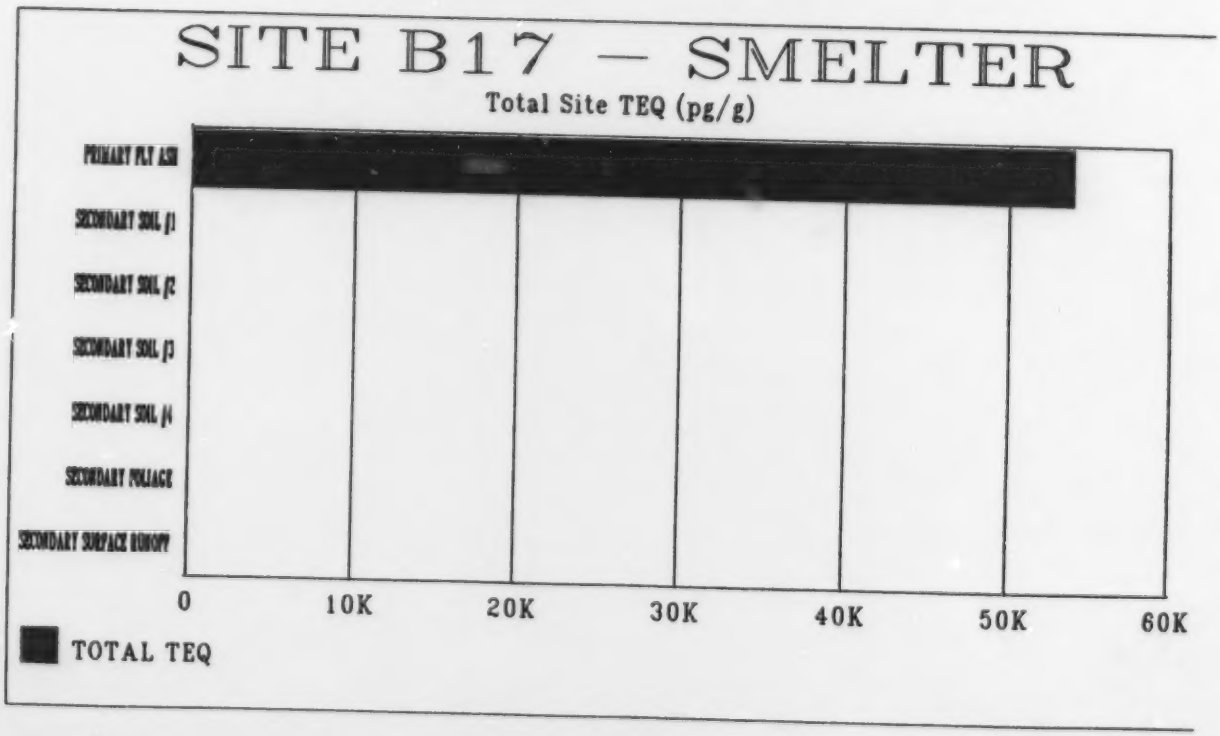


FIGURE 28 **Site B17. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs). (Note: Fly ash included; Runoff expressed as pg/ml to facilitate comparison with pg/g).**

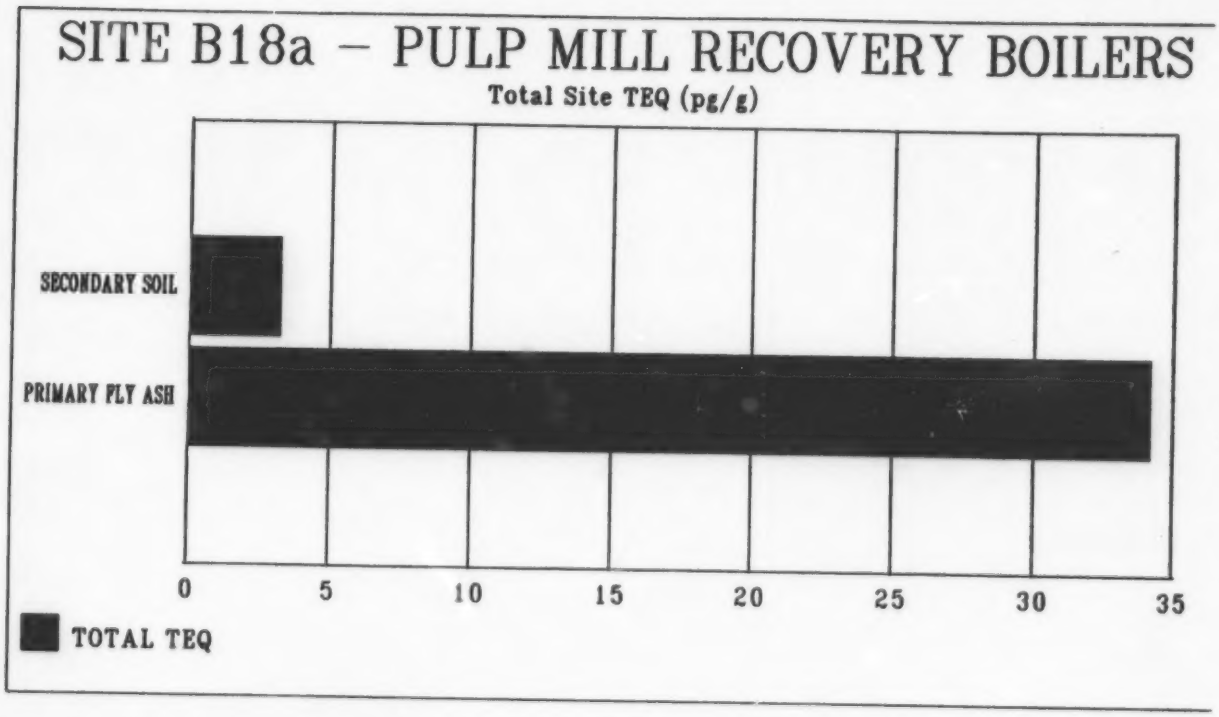


FIGURE 29 **Site B18a. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**

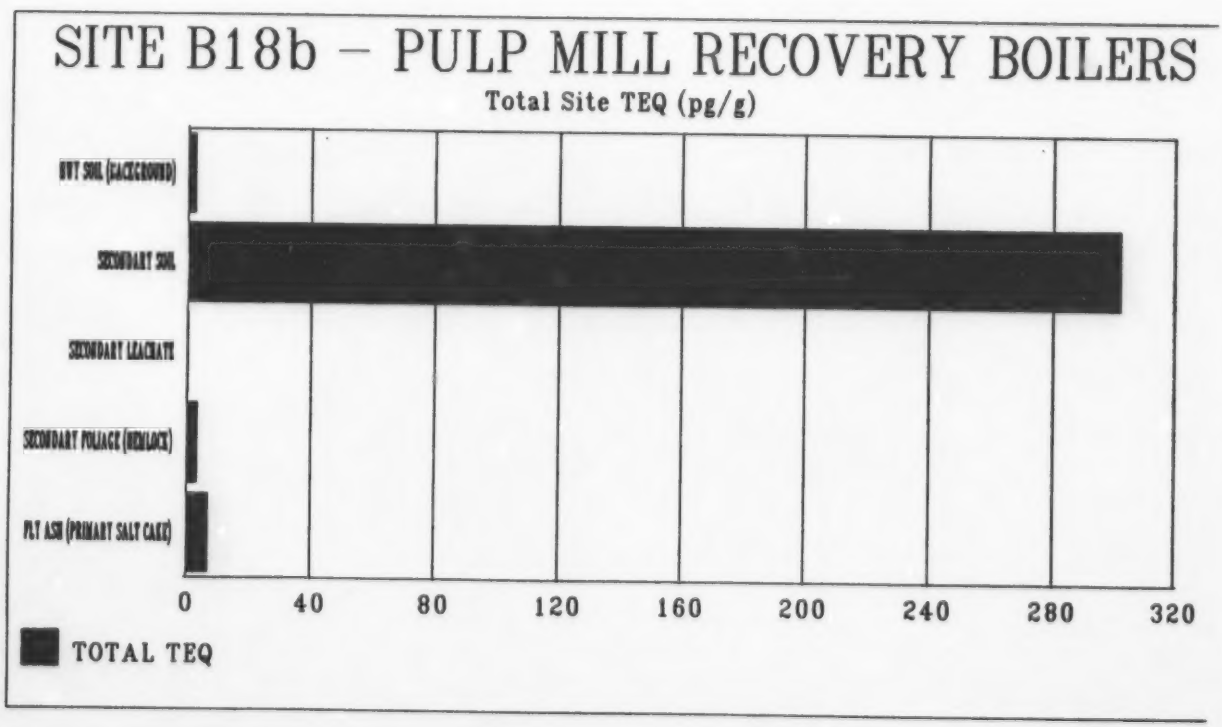


FIGURE 30 **Site B18b. Dioxin and Furan Levels (2,3,7,8 TCDD-TEQs).**
(Note: Leachate expressed as pg/ml to facilitate comparison with pg/g).

FIGURES 31-33

SUMMARY OF TOTAL 2,3,7,8-TC_4DD TEQ LEVELS IN THE B.C. ENVIRONMENT

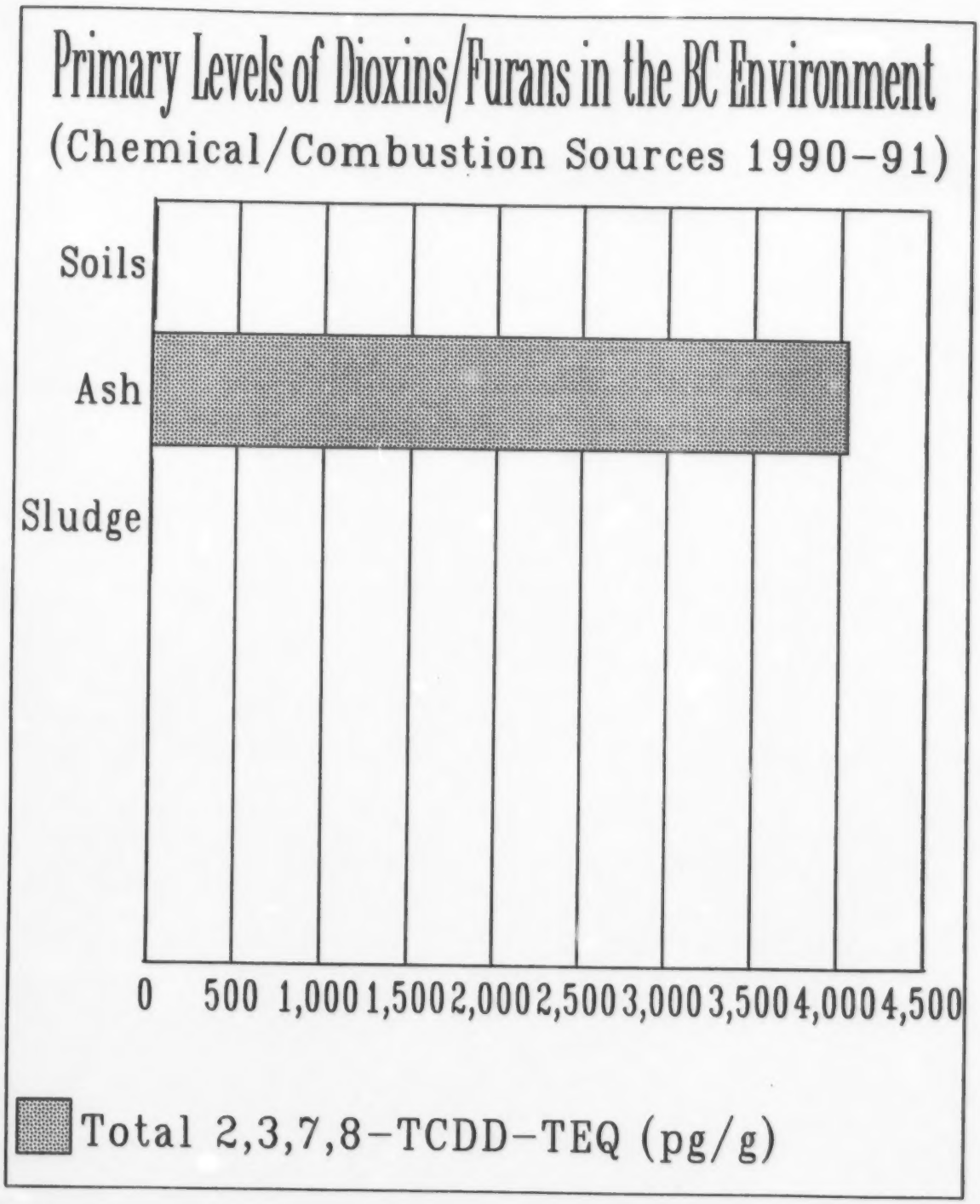


FIGURE 31 **Primary levels of dioxins/furans in the B.C. Environment.**

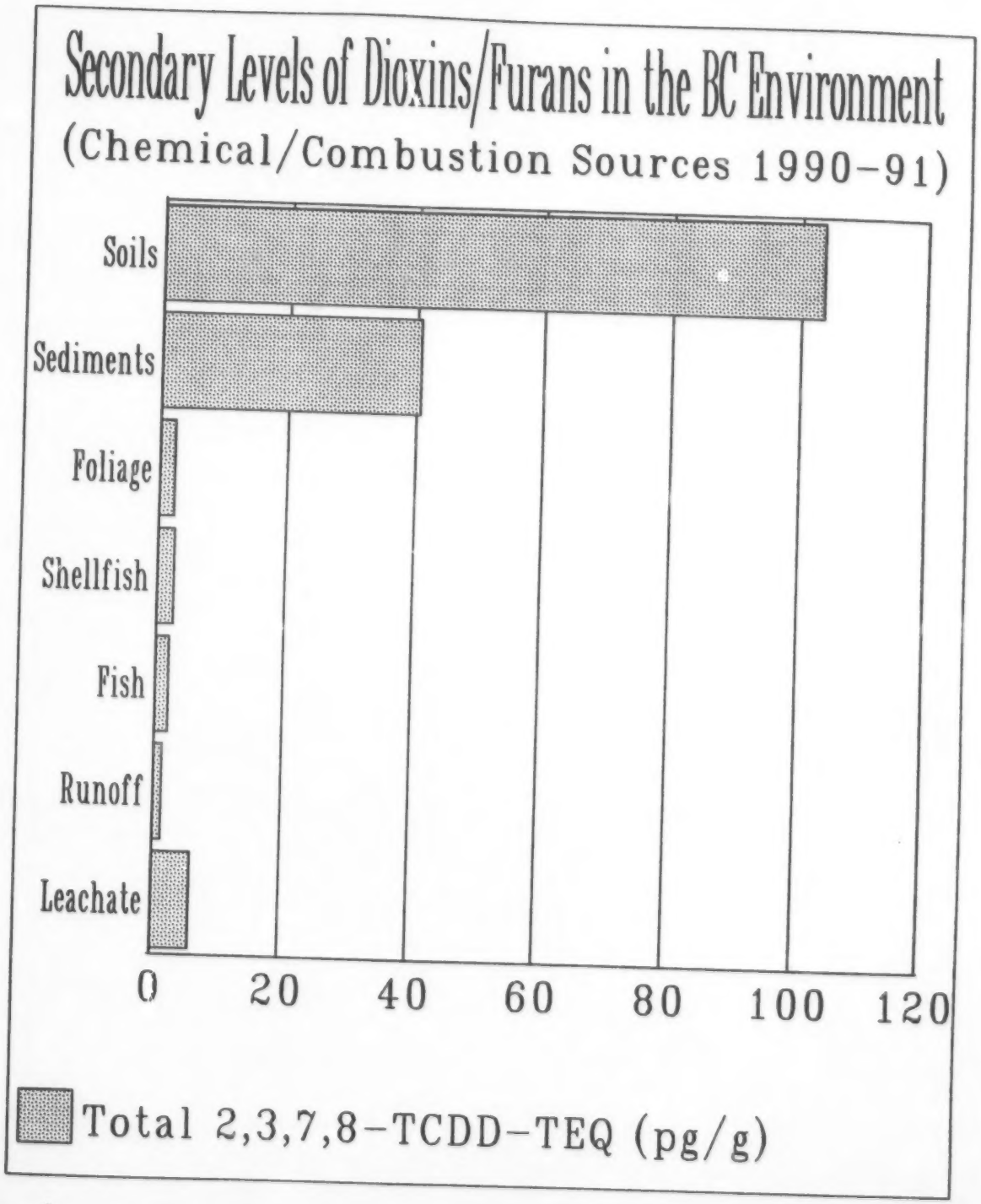


FIGURE 32 **Secondary levels of dioxins/furans in the B.C. Environment.**

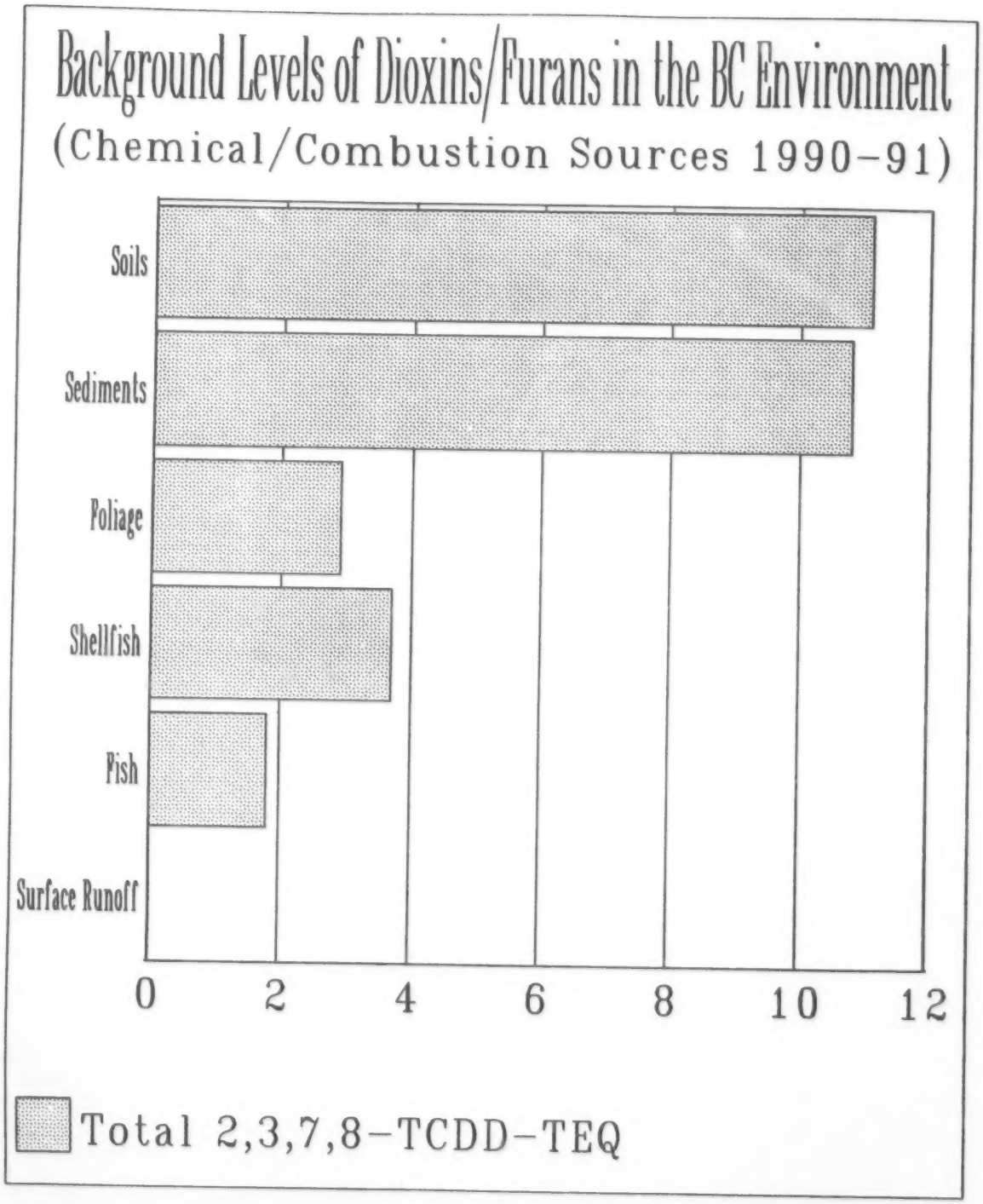


FIGURE 33 **Background levels of dioxins/furans in the B.C. Environment.**